The Super-Machine Gun

ARMY ORDNANCE

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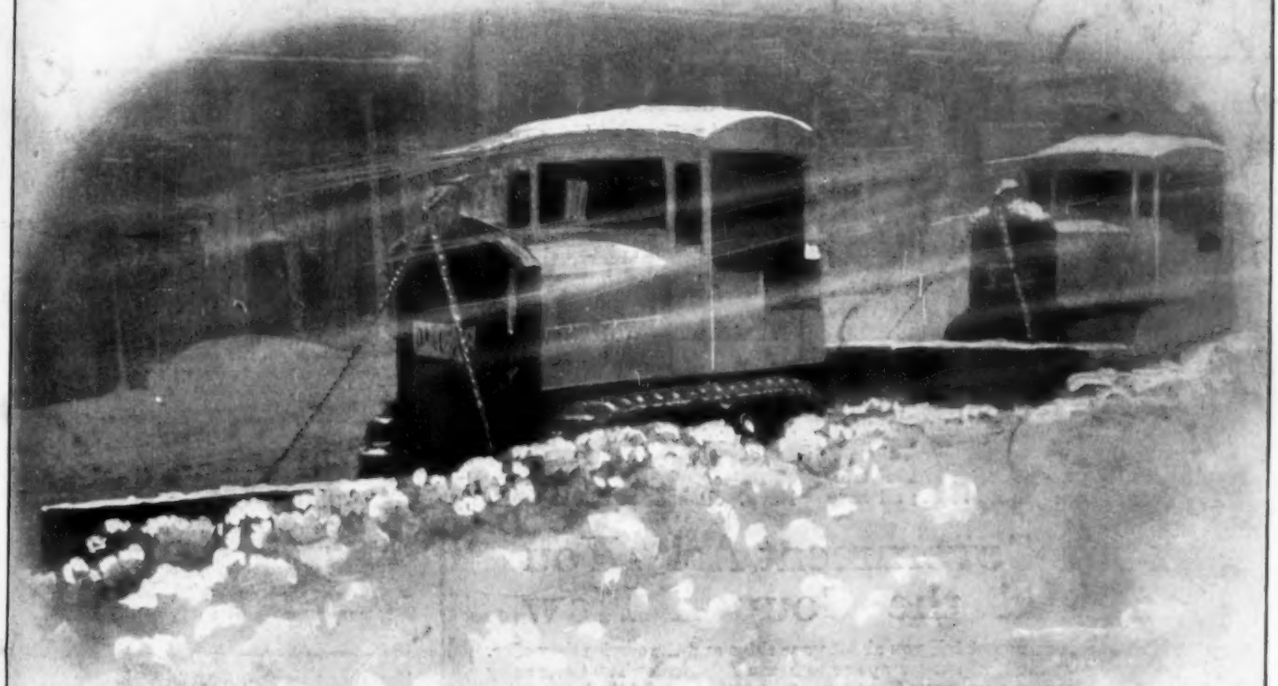

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THE JOURNAL OF THE ARMY ORDNANCE ASSOCIATION

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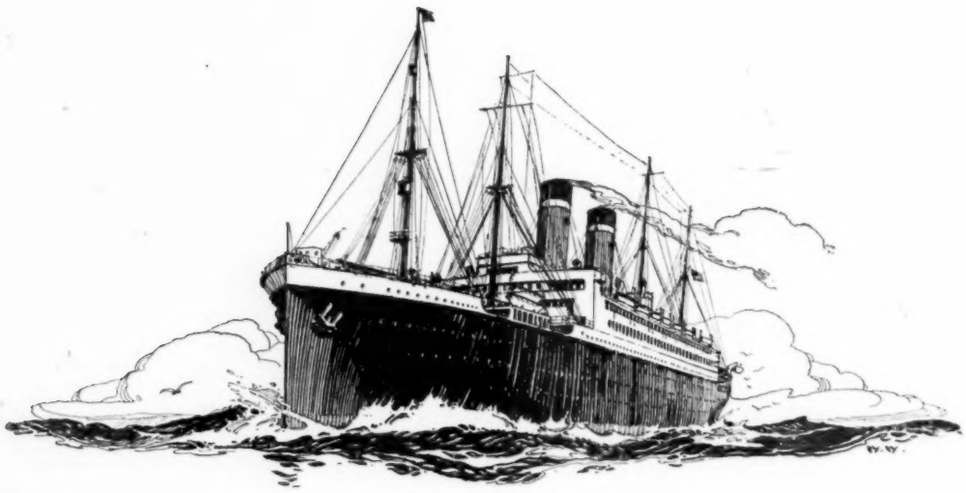

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ARMY ORDNANCE

THE JOURNAL OF THE ARMY ORDNANCE ASSOCIATION

Pledged to Public Service in Effecting Industrial Preparedness for War as Our Strongest Guarantee of Peace

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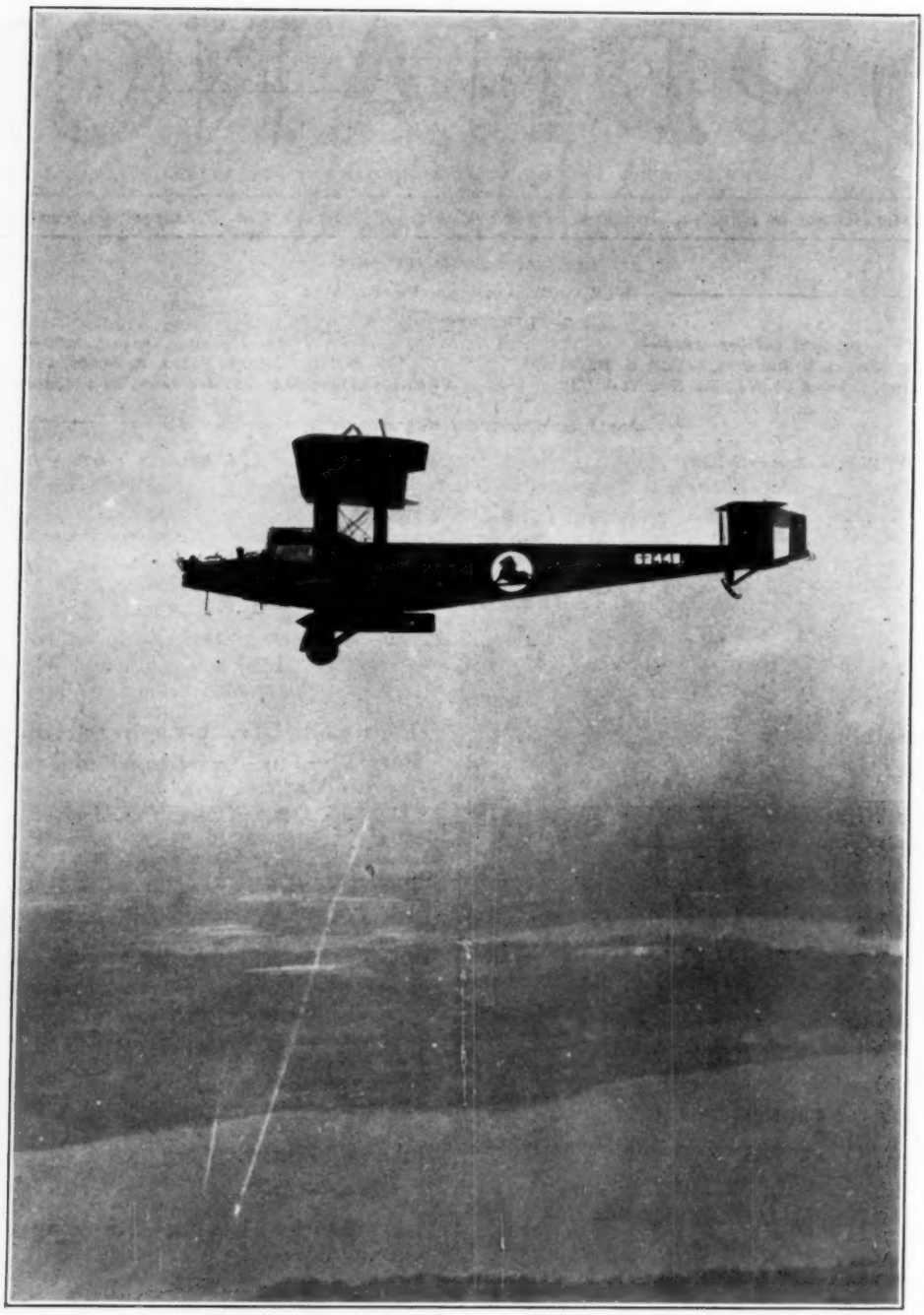


The Biggest Bomb Ever Dropped from An Airplane

4,000-Pound Demolition Bomb, Designed and Manufactured by the Army Ordnance Department, Slung Under Handley-Page Bombing Plane in Flight Over Aberdeen Proving Ground, Just Before Bomb Was Released in First Official Test

Note comparative size of bomb and aviators in forward cockpit

The Super-Machine Gun

By

HERBERT O'LEARY

Member A. O. A.

A MACHINE gun far more powerful than any other similar weapon heretofore used has recently been developed and perfected for our Service. This gun is known as the Browning .50-caliber Machine Gun, and its successful development is without doubt the most important and interesting development in the Small Arms field since the World War, and perhaps one of the most interesting in the whole field of Ordnance. A few words relative to this remarkable achievement will, therefore, probably be of interest to those who are following current progress in Ordnance design.

However, before proceeding with a description of the weapon, it may be well to present a brief historical sketch of machine gun development, which led up to and made logical the idea of a super-machine gun of the greatest possible power consistent with the extremely light weight which conditions governing the use of such a weapon make most essential.

Colonel Herbert O'Leary

The desire for a machine-gun which would fire small arms ammunition automatically at a great rate of speed dates back almost to the beginning of the successful development of firearms. However, the first really successful weapon of this character did not appear until 1884, when the Maxim Machine Gun, invented by Hiram Maxim, an American who lived in England, was perfected. From this time until the beginning of the World War many different successful types made their appearance, but, with very few exceptions, all of them were mere adaptations or modifications of the original Maxim Machine Gun. One of these exceptions, the Colt caliber .30 machine gun, is of particular interest to us, inasmuch as it was invented by Mr. J. M. Browning and was used by our Army and Navy for a long time.

Prior to the World War each principal nation had adopted one or more of the principal types of machine guns as a part of the equipment of its armies, but it was not until after the war had been in progress for some time that most people began to realize the enormous possibilities and importance of these weapons as instruments of war. In fact, they were considered auxiliary to the major equipment, and at least in our service, were looked upon by many with distrust, because it was believed that they could not be depended upon to function at the critical moment. The war has changed all of this, and to-day machine guns are considered of the utmost importance, and there is universal confidence in their ability to "deliver the goods" when called upon to do so.

In August, 1914, the caliber of the standard machine gun of each nation was the same as the caliber of the infantry weapon of that nation, and in most instances they fired identically the same ammunition. The principal role assigned to machine guns at that time was that of supplementing rifle fire against targets assigned to the Infantry and the Cavalry, and they were therefore issued to Infantry and Cavalry units almost exclusively. The war had not been under way long, however, before new fields of usefulness began to be found for these weapons, and coincident with these new uses, insistent demands for guns especially designed for particular purposes began to be heard, until at the end of the war we find several distinctive designs in general use, among which might be mentioned the ordinary ground type of weapon used to supplement rifle fire and to provide overhead cover for advancing troops (barrage fire); the anti-aircraft type for use from the ground against aerial targets; the tank type for arming tanks and the flexible and synchronized aircraft types for arming airplanes.

One of the first departures from the pre-war conception of the proper use of the machine gun was its use in aerial combat, both defensively against attacking opponents in the air, and offensively against enemy airplanes and ground targets. At the same time their use from the ground against low-flying airplanes was being developed, and strenuous efforts began to be made to improve their effectiveness when used either from the ground or in the air against aerial targets.

To say the least, an airplane in motion is a very fleeting and elusive target. Its speed and the length of time it is within range hardly make it possible for a gunner to take deliberate aim as can be done in the case of a stationary or slow-moving target, and this makes the ordinary type of machine gun or rifle sight all but worthless. In order to make

the aiming of machine guns used against such targets easier and more certain, the expedient was adopted of using a hollow bullet containing a chemical mixture, which is ignited by the powder charge in the cartridge when the machine gun is fired, and which burns during the flight of the bullet with a bright light, which is visible to the gunner. By loading the belts or magazines so that every fifth or sixth cartridge is one having a tracer bullet, it is possible for him to actually see the path of the bullet and to quickly so direct his gun that hits will be registered on the target. At the same time that this tracer ammunition was being developed for war use, the inflammable nature of aircraft and of captive balloons used for observation purposes brought home the desirability of devising ways and means of setting them on fire. To meet this requirement, incendiary ammunition was developed. This ammunition consists simply of a hollow bullet filled with phosphorus, which burns during the flight of the bullet, and which will set fire to inflammable material with which it may come into contact.

Fig. 1—German 13-mm. (.511-inch) Mauser Rifle

The small caliber of all machine guns used up to this time limited the effectiveness of these special types of ammunition very materially, but the French had a cartridge 11 mm. (.433″) in caliber, which had been developed in 1874 for use in the French rifle of that caliber, and an investigation indicated that Vicker's machine guns of British and American calibers (.303″ and .30″) could easily be changed so as to fire this larger cartridge. The bullet of this cartridge is approximately 50 per cent greater in diameter than the bullet of the .303 and .30 cartridges, which made possible the design of a more effective incendiary bullet. This, accordingly, led to the development and use of the 11-mm. machine gun, a machine gun greater in caliber than any theretofore in general use in the war.

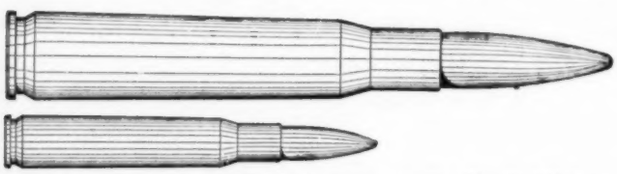


Fig. 2—Upper: .50-caliber Cartridge. Lower: .30-caliber Cartridge

Now, going back for a moment to the use of machine guns by Infantry and Cavalry troops, these weapons were early in the war found to be of considerable use for delivering barrage fire, although their use for this purpose was limited, inasmuch as the extreme range at which available machine guns could be used for this purpose did not, in our service, greatly exceed 2,800 yards, and in no service were machine guns available which could be used for this purpose at ranges in excess of 3,800 yards. As the importance of machine gun barrage fire grew, the limitations of existing types of weapons for this purpose became more apparent, and an insistent demand for an ammunition having a greater effective range than any used in our service before this time began to make itself felt, and the necessary development work was accordingly undertaken. This question of increasing the effective range of machine guns gradually gave rise to the idea of designing and building a new gun of greater power and range than any before undertaken. About this time another consideration arose which gave added impetus to the idea of a super machine gun. Rumors began to be heard of airplanes about to be put into service by the Germans, which were to be protected by armor of such thickness that armor-piercing bullets fired from machine guns in use at that time would be wholly ineffective against them. The obvious answer to this rumored new move on the part of the Hun was a machine gun of sufficient power to penetrate armor of any thickness practicable for him to employ.

To meet these increasing requirements for a high-powered machine gun, the British began experimental work on a large caliber cartridge early in the summer of 1917, but so far as is known, no definite results were obtained. During the latter part of 1917 the development of a large caliber, high-powered machine gun began to be seriously considered in this country, and early in 1918 it was definitely decided to proceed at once with the development of both gun and ammunition.

The question of the design of the gun was referred to Mr. J. M. Browning, probably the foremost inventor of automatic small arms weapons in the world, and the inventor of the caliber .30 Browning machine gun, the caliber .30 Browning automatic rifle, and the caliber .45 automatic pistol, all of which are standard weapons in our service and unexcelled by any similar weapons in use by any other nation. The problem of designing and manufacturing the ammunition in accordance with general specifications drawn up by the Ordnance Office, was at first referred to the Winchester Repeating Arms Company of New Haven, Conn., but later was transferred to the Frankford Arsenal, Philadelphia, Pa.

Before actually undertaking the design of this weapon, it was generally agreed that the design of the Browning caliber .30 machine gun, which gave such a satisfactory account of itself, should be followed in so far as practicable in the design of the larger machine gun. After an exchange of views with the A.E.F. and an investigation of the work which had been done in England towards the development of a large caliber machine gun, it was decided that the new weapon should be one-half inch in caliber, and that its minimum effective range should be not less than six thousand yards. It was further decided that the cartridge case should have a cannelured head similar to the model of 1906 ball ammunition, and that the weight of the bullet should be from six hundred to seven hundred grains, and that the muzzle velocity should be at least 2,400 feet per second within a maximum permissible chamber pressure of 52,000 pounds per square inch. As soon as the general specifications were agreed upon, active work

was initiated, and the first gun, which was of the water-cooled type, was delivered in August, 1918.

This gun fired at the rate of approximately 500 rounds per minute and weighed approximately sixty pounds. The ammunition had a bullet weighing 707 grains and was loaded with 150 grains of powder, and developed a muzzle velocity of 2,400 feet per second. By using a lighter bullet, weighing 510 grains, and 162 grains of powder, it

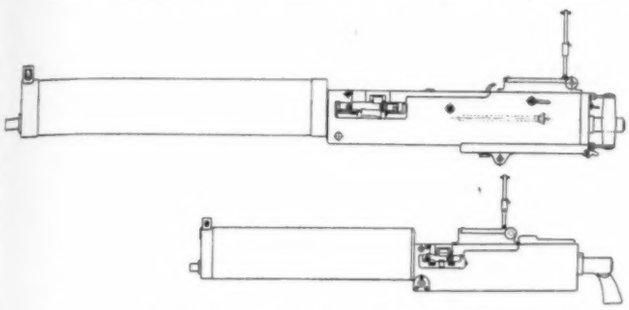


Fig. 3—Browning Water-cooled Machine Gun
Upper: .50-caliber. Lower: .30-caliber

was possible to obtain a muzzle velocity of 2,800 feet per second. The functioning of this weapon was so satisfactory that directions were immediately issued for the construction of a model suitable for mounting on aircraft. This was deemed advisable, owing to insistent demands received from the A.E.F. that the aircraft model be given precedence over all other models, in order that a weapon suitable to combat armored airplanes, which it was feared would shortly make their appearance, would be available. Before this new model was completed, the Armistice was signed, and owing to the change brought about in the military situation by this event, the early perfection and manufacture of these large caliber machine guns became less urgent. Development work, accordingly, practically ceased, in order to permit of a more thorough study of the ballistic requirements and possibilities of a weapon of this caliber and its ammunition, so that the gun, when finally perfected, would in so far as possible meet all requirements.

Several months after active work was begun on the .50 caliber machine gun, a new cartridge designed and used by the Germans made its appearance on the western front. This cartridge had a bullet approximately one-half inch in caliber, and was used in combating tanks which carried considerable armor. The weapon from which the cartridge was fired is a single shot rifle, in every way similar to the Mauser rifle with which the German infantrymen were armed, but of necessity larger in every respect. Fig. 1

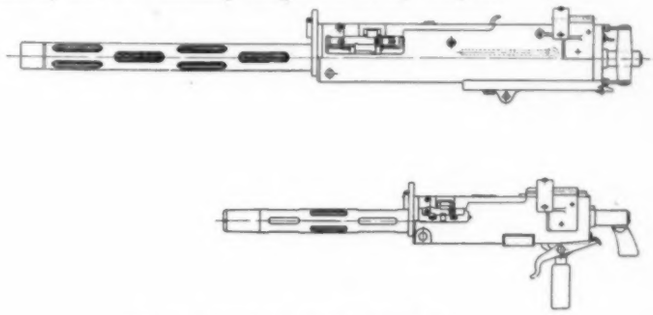


Fig. 4—Browning Tank Machine Guns
Upper: .50-caliber. Lower: .30-caliber

is a reproduction of this large German Mauser rifle. The rifle is five feet long and weighs approximately forty pounds, complete with its bipod mount. The ammunition, as designed, was very well thought out, and tests indicated that it would penetrate approximately one inch of good armorplate. The bullet was stream line (boat-tail) in form and weighed 51.4 drams. A thorough investigation of this German cartridge made it desirable to re-design the caliber .50 cartridge previously developed by us, in order that our ammunition might at least be the equal of any other ammunition known. This resulted in a much more powerful cartridge, which in turn made necessary a slightly heavier gun. The cartridge finally adopted is shown on Fig. 2. The size of this cartridge, compared to the regular caliber .30, model of 1906, service cartridge with which every one is familiar, is also indicated. The complete caliber .30 service cartridge weighs approximately three hundred grains. Its powder charge weighs about 48 grains, and the weight of the bullet it 150 grains. The complete caliber .50 cartridge weighs approximately 1,890

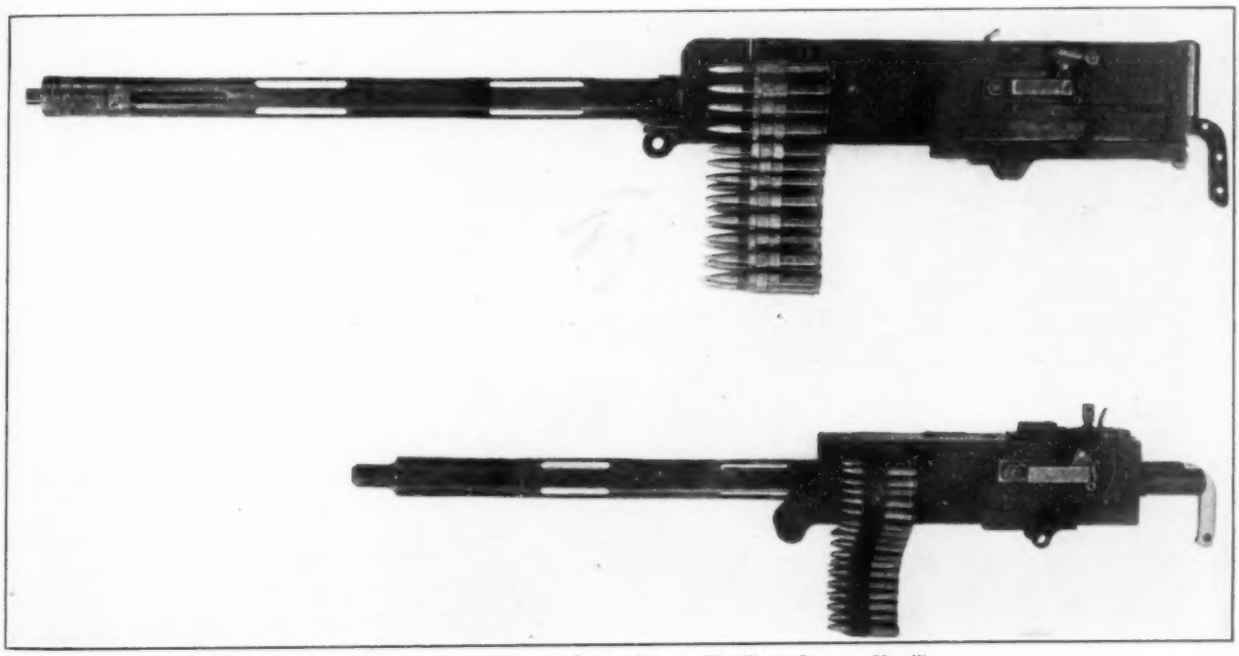


Fig. 5—Browning Aircraft Machine Guns. Upper: .50-caliber. Lower: .30-caliber

grains. It is loaded with approximately 235 grains of powder, and its bullet weighs 804 grains. It takes about twenty-three caliber .30 cartridges to weigh a pound, and only four caliber .50 cartridges. In other words, the caliber .50 cartridge is six times as heavy as the service cartridge.

As soon as the design of the improved type of cartridge had been determined upon, a definite and specific program for the completion of the development of the machine gun itself was laid down. This program involved the design and manufacture of a limited number of each of three

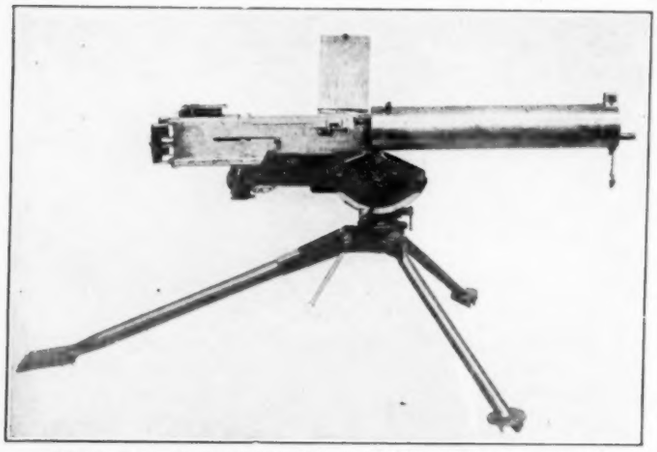


Fig. 6—Browning .50-caliber Water-cooled Machine Gun and Tripod

distinct types of gun; namely, the water-cooled type for use on the ground against ground targets, the anti-aircraft-tank type for use on the ground against aircraft and for mounting in tanks, and the aircraft type for mounting in airplanes for use against ground targets or enemy aircraft. The design of these three has been carried along together, and an endeavor has been made to make as many parts as possible common to all types. Samples of all three have been delivered and tested, and preliminary trials indicate that the program has been a success in every way. An idea of the size of the completed caliber .50 water-cooled machine gun, as compared to the standard caliber .30 Browning water-cooled machine gun, may be obtained by reference to Fig. 3. In the same manner, Fig. 4 shows the relative sizes of the anti-aircraft-tank caliber .50 gun and the caliber .30 gun of the same type, while Fig. 5 shows the same comparison between the Browning .50 and .30 caliber aircraft machine guns.

The Browning .50 caliber machine gun as finally perfected is a recoil operated weapon, is belt fed and fires at the rate of approximately 550 shots per minute. Its operating principle is the same as that of the caliber .30 Browning machine gun. In the design of the weapon the minor defects in the caliber .30 Browning machine gun, which were brought to light by field use, were corrected in the larger caliber weapon, and minor improvements which appeared to be necessary were incorporated. One important feature which does not exist in the smaller weapon was included in the .50 caliber gun. This feature is a hydraulic buffer, designed for the purpose of quickly absorbing the greater portion of the enormous energy of recoil which is developed every time the gun is fired. The water-cooled gun weighs approximately 66 pounds without water and 82 pounds with the water jacket filled. The water jacket has a capacity of eight quarts of water, which reaches the boiling point after 300 rounds of continuous firing. It is mounted on a tripod which weighs 80 pounds. Fig. 6 illustrates this weapon, mounted upon its tripod. When fired, the gun imparts a muzzle velocity of 2,500 feet per second to the 804 grain bullet, and its maximum range is 9,000 yards. Fig. 7 is a graphic comparison of the trajectories of the caliber .50 bullet fired from the water-cooled machine gun, and the ordinary caliber .30 150-grain bullet in regular use in our service.

The high state of development and the efficiency of this weapon, as well as the complexity of the design problems, may perhaps be visualized by making a comparison with certain well known types of gas engines. The Browning anti-aircraft .50 caliber machine gun develops 204 horsepower, or one horse power per .255 pounds. The Browning caliber .50 water-cooled machine gun develops the same horsepower, or one horsepower per .294 pounds of weight. The weight per horsepower developed by well known types of gas and steam engines is as follows:

Liberty Motor: 4.5 pounds per horsepower.
Automobile Motor: 8 pounds per horsepower.
Commercial Gas Engine: 150 pounds per horsepower.
Tractor Engine: 200 pounds per horsepower.
Steam Locomotive: 600 pounds per horsepower.

Weight for weight, the Browning .50 caliber water-cooled machine gun develops more than fifteen times the energy of the Liberty Motor.

The field of usefulness of this weapon is very large, but probably the most important of all is its use from the ground against aerial targets, that is, for anti-aircraft defense purposes, and in view of recent tests which demonstrate the enormous destructive power of bombs dropped from aircraft, it might be well to draw particular attention to its possibilities in this connection. This weapon is capable of projecting bullets into the air, each weighing one-ninth of a pound, at the rate of 550 to 600 per minute, or ten per second. The initial velocity is such that the effective range against aerial targets is estimated to be at least 1500 yards, or 4500 feet, and one hit on a vital part of an airplane at this range will be disastrous. This means that in manœuvers, such as bombing, directed against objects on the ground, which are properly protected by these guns, it will be necessary for an airplane to fly above this altitude in order to keep out of range, and this in turn means much less effective work. On account of its rapidity of fire and its high velocity, it is confidently believed that this weapon is by far the most effective weapon for use from the ground against attacking airplanes, which has been developed to date.

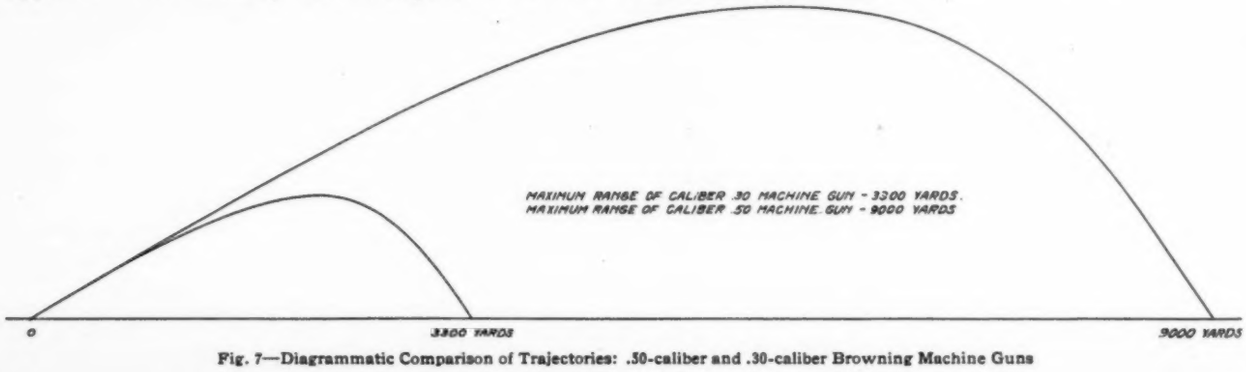

MAXIMUM RANGE OF CALIBER .30 MACHINE GUN - 3300 YARDS.
MAXIMUM RANGE OF CALIBER .50 MACHINE GUN - 9000 YARDS
0
3300 YARDS
9000 YARDS

Fig. 7—Diagrammatic Comparison of Trajectories: .50-caliber and .30-caliber Browning Machine Guns

The Biggest Bomb in the World

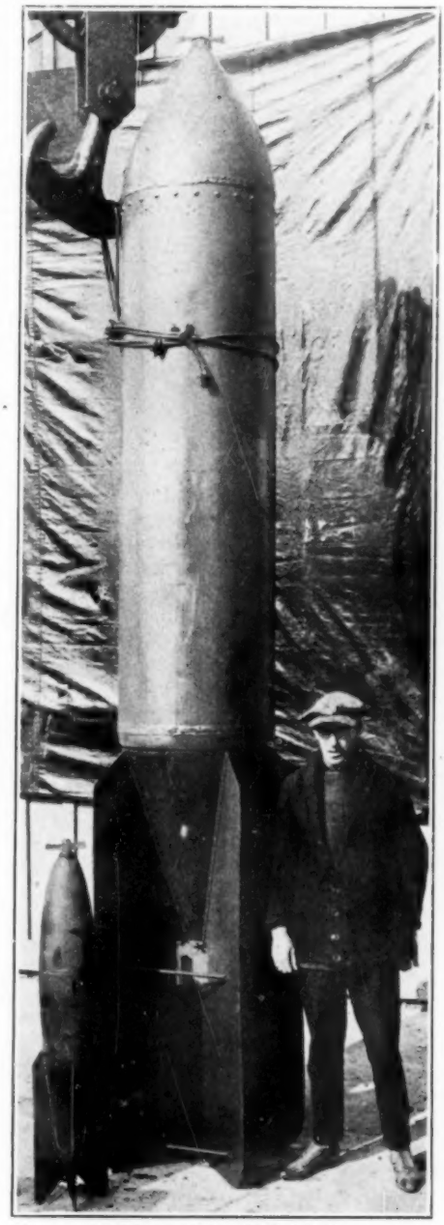
By

WM. A. BORDEN

Member A. O. A.

At the recent meeting of the Army Ordnance Association at Aberdeen Proving Ground an opportunity was afforded those present to see the latest development in aircraft bombs—the 4,000-pound Demolition Bomb, probably the largest bomb in the world. It is doubtful, however, if many members of the Association, not to mention the general public, whose impression has been gained in motion pictures, fully appreciate the great size or destructive power of this super bomb. The accompanying illustration of the bomb in an upright position with a man on one side and a 100-pound Demolition Bomb on the other gives a good idea of its relative dimensions. It measures 13½ feet in height (from fins to nose). It is nearly 2 feet in diameter, and has an actual weight of about 4,300 pounds, of which approximately 2,000 pounds is high explosive. So far as is known, no other country has produced a similar weapon of such size.

It was designed by the Aircraft Armament Division in the Office of the Chief of Ordnance, for use by the largest bombing aircraft in the attack of naval vessels of the most modern battleship type and in raids against great munition plants. Careful consideration was given to all results obtained in previous experimental work, and in the design are embodied all the latest improvements. Although constructed to penetrate without deformation or fracture the usual targets against which it might be used, it is not constructed to go through heavy armor. In addition to being made strong enough to withstand impact, the case is proportioned to hold as much explosive as possible, for it is mainly upon the amount of explosive carried that the destructive effect of the bomb is dependent. Fuses in the nose and tail of the bomb have been designed to give either instantaneous action or delayed action, permissible delays ranging from a few hundredths of a second up to several seconds. Taken as a whole, the bomb may be considered the most powerful and efficient weapon of its type yet produced.



4,000-pound Demolition Bomb
100-pound Demolition Bomb at the left

In the test the bomb was carried in the air by an American-made Handley-Page, and in order that the airplane might lift this great weight it was stripped of all its extra military load, the fuel tanks were but partly filled, and the pilot, bomber, and one mechanician were the only ones allowed to make the flight. Taking off with such a load was in itself a dangerous venture, and added to this was the hitherto untried experiment of releasing so much weight at one time from an airplane. Capt. Norbert Carolin, the pilot; Sergt. Stewart Smink, the bomber; and Corp. Louis Averitt, the mechanician, deserve great credit for undertaking the initial flight with this bomb.

The observers witnessed the test from the main front of the Proving Ground, about 2,000 yards from the point over which the bomb was dropped. As the airplane approached the bomb could be seen very clearly suspended in position under the fuselage, and when released it dropped in perfect flight, nosing down slowly with fins guiding it on its curved path through the air. Asked later concerning the effect of the release, the pilot stated that the airplane shot up about twenty feet, but this was no worse than a bad "bump," often encountered in flying.

When the bomb struck the ground, great masses of earth, debris, and smoke were hurled hundreds of feet in the air, and several seconds later came the tremendous crash of the detonation. A delay of a few hundredths of a second was used to allow the bomb to penetrate the ground to form a crater, thus limiting the distribution of fragments from the bomb case and eliminating the possibility of any one of these fragments being projected as far as the observing party, which might have occurred had an instantaneous fuse been used. The blast from the detonation was largely smothered by the formation of a crater, and some of the observers were disappointed that the effect from the detonation was not appreciably felt, but when the smoke and dust had cleared away the power of the bomb was shown by the

Exterior Walls of the Crater. Mounds of earth five feet high were formed around the edge and gave the crater the appearance of a small fort

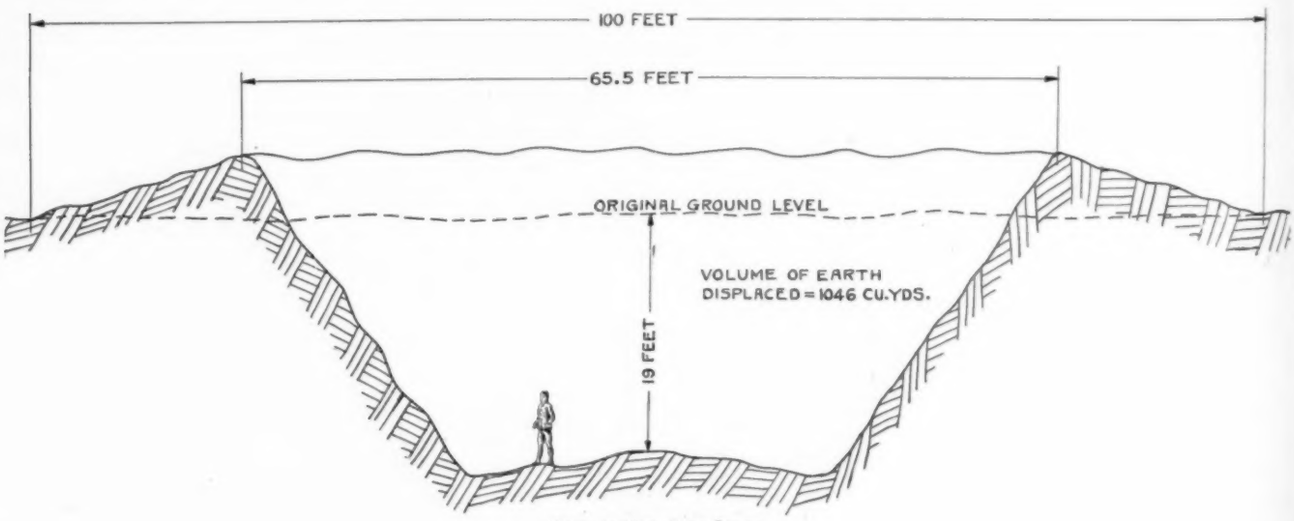
immense crater formed. To those who did not see it, a glance at the cross-section through the crater and the pictures will show how large it was. One thousand and forty-six cubic yards of earth were displaced and a hole 19 feet deep by 65 feet in diameter was blasted in the earth. It was a remarkable sight, and was probably the largest crater ever formed by a projectile.

This was the first of a series of tests to be conducted with the 4,000-pound bomb. Some who witnessed it may well wonder if there will be need for so large a bomb. There is no doubt of this, only the tactical use of such a great weapon remains to be determined. In this 4,000-pound bomb a design has been worked out which is easily capable of expansion, and as the carrying capacity of aircraft increases can be extended to bombs of even larger size as such are needed.

Looking Down Into the Crater
The picture takes in only a part of the crater. The man is six feet tall

As a result of these tests, the Army Ordnance Department can state authoritatively that it is in a position to manufacture demolition bombs up to and including the maximum weight which can be lifted and transported by any bombing plane as yet produced and operated under service conditions by our aviators. Furthermore, these bombs can be and have been, built according to designs yielding both the greatest safety to the operating personnel and a maximum destructive effect when released upon an enemy target. By safety to operating personnel is meant that the bomb shall be inert chemically and mechanically during manufacture, storage, transportation, and the operation of suspending it under the fuselage, and that it shall remain harmless while suspended from the plane not only while "taking off" and cruising in the air, but that it shall be impossible of accidental detonation in the event of a forced landing or even an untimely crash. Under the latter conditions, while the bombing personnel might conceivably be seriously injured or killed by the fall, regardless of the action of the bomb carried under their plane, it is nevertheless vitally important that the bomb should not detonate under these conditions due to the danger to friendly personnel.

It is also necessary to provide for the contingency which might arise when it would be extremely desirable to actually drop the bomb, but to drop it as a "dud"—that is, to drop it with the assurance that it would not detonate on impact. In the design of all demolition bombs so far produced by the Army Ordnance Department it is believed that a satisfactory solution to these perplexing problems has been found.



Cross-section of the Crater

Improved Small Arms Ammunition

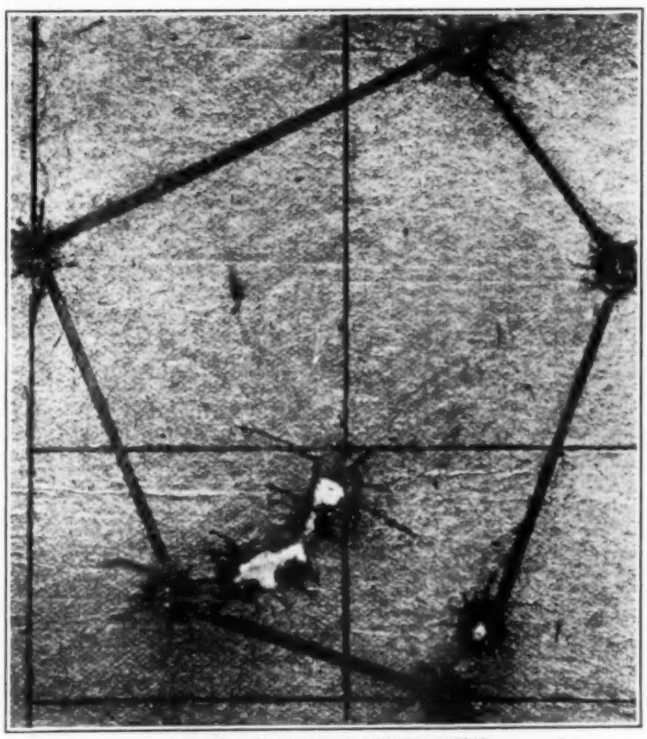
By

TOWNSEND WHELEN
Member A. O. A.

[Prior to the World War, Colonel Whelen was serving as Captain, 29th Infantry. On the outbreak of the war he was assigned as Major and Ordnance Officer, 79th Division, and assisted in equipping and training that division. It is interesting to note that this was the first division to be completely equipped with Browning Machine Guns. Two days before the 79th Division sailed for France, Major Whelen was detailed as a member of the General Staff Corps, and ordered to Washington for duty in the War Plans Division, where he remained during the war in charge of Infantry Training in the United States, particularly training in marksmanship and musketry, of which he had made a specialty. He was promoted to the grade of Lieutenant-Colonel in June, 1918. His work on the General Staff brought him into very close touch with the Ordnance Department, and it was natural that he shou'd have transferred to that corps after the war. He is at present in command of Frankford Arsenal.—ED.]

THE United States has always been to the fore in the character and development of its small arms ammunition. We have many incentives to encourage such work. Not only do we strive to keep abreast of other nations, but we are driven and encouraged by a very critical and demanding class of small arms users, both military and civilian. The rifleman of America differs greatly from his brothers of other countries. He is not willing to take what is given him, but demands the very best, and he knows what is the best because he is a very close student of small arms ballistics and mechanics. For example, we find even civilian riflemen in this country loading their own ammunition and developing their own charges, and there is a host of amateur experimenters. The largest users of small arms are of course the Infantry of the Regular Army and National Guard, and they too are very critical and demand the best, for they say that without the best ammunition they cannot develop that nail-driving marksmanship which should be a characteristic of the United States Infantry.

The Ordnance Department has endeavored and has succeeded in keeping in the closest touch with all the using services and classes, and it is a matter of pride with us that we have not only kept abreast of their demands, but have actually given them better ammunition than they asked for or believed possible. The improvements and developments in the various types of ammunition will be discussed seriatim.



RECORD-BREAKING AMMUNITION

For the 1921 National Matches the Army Ordnance Department manufactured .30-caliber ammunition which broke all previous records at all ranges.

The illustration is a ***full size*** reproduction of the entire portion of a target pierced by successive bullets during the Official Test, and shows clearly the phenomenally low dispersion obtained at ***six hundred yards.***

Target 15-C-28, 600 Yards. Official Test National Match Ammunition, 1921. Frankford Arsenal. 170-gr. Tinned Bullet; 48.5 grs. DuPont EX-1076 Powder.

Mean radius	1.28 inches	Extreme vertical	3.55 inches
Mean vertical	.93 inches	Extreme horizontal	3.20 inches
Mean horizontal	.76 inches	Mean error	2.24 inches
Group diameter	3.56 inches		

Ball Ammunition, Caliber .30

The service type of a year ago contained a 150-grain pointed cupro-nickel jacketed bullet and sufficient of Pyro D. G. (nitrocellulose, regular burning) powder to give a muzzle velocity of 2,700 feet per second. The mean radius at 600 yards was about 5 inches. Practically its group of shots could be contained in about a 22-inch circle at that range. This ammunition, while superior in most characteristics to that of any other nation, was not quite what was desired in several respects. The best criticism of it comes from the using services, particularly from The Infantry Board. It asks for a service ammunition which shall have better accuracy, which shall give no metallic fouling, which shall have the flattest possible trajectory up to 1,000 yards, and which shall be least deflected by wind. These are requirements for ammunition for riflemen only; machine gun service ammunition will be dealt with later.

In endeavoring to fulfill these requirements certain things had to be overcome. Thus, given a perfect bullet and a suitable powder, inaccuracy is caused by the deforming of the bullet as it passes from the case, through the bullet seat, into the bore; by a deformed or untrue base causing a deflection at the muzzle; and by excessive fouling in the bore. These troubles had to be overcome in order to increase accuracy.

Metallic fouling is caused by the friction of the bullet jacket against the bore at high speed and under high pres-

sure. Examined under a magnifying glass the surface of the bore is very rough, and can be likened to a file. Particles and lumps of the jacket scrape off and adhere to these rough places, causing obstructions to the bore which interfere with accuracy, and make cleaning very difficult, in many cases causing the deterioration of the bore before it is worn out by erosion. Cupro-nickel jackets are particularly bad in this respect, adhering to the bore in large lumps which can plainly be seen by examining the bore from the muzzle. The fouling always occurs near the muzzle; and hardly ever near the breech due to the volatizing effect of the heat of the powder gases.

Jackets of gilding metal (copper 90 per cent, zinc 10 per cent) are much better in this respect, giving only a thin almost invisible film of copper throughout the bore which does not interfere with accuracy. In fact gilding metal would be an ideal bullet jacket material, not only on account of its characteristics but because it is easily obtainable in good quality in the United States in war time, were it not for the fact that it is soft and does not resist deformation well during the passage of the bullet from the case, through the bullet seat, into the bore. Hence so far we have not succeeded in obtaining as good accuracy from gilding metal as from cupro-nickel jackets.

The combining in gilding metal of 1 per cent of tin to make it stiffer and harder has been tried, but so far difficulties have been experienced in getting the alloy too brittle under quantity production methods. The effect of tin in the elimination of metallic fouling in heavy ordnance was of course known. At first the experiment was tried of incorporating tin, and also an alloy of tin and lead, with the powder to the amount of between 3 per cent and 5 per cent. This worked quite well, but it was a very expensive method, as it greatly increased the cost of the powder. The thought then occurred at Frankford Arsenal—why not put the tin on the bullet? A thick, even tin coating to the bullet should not only prevent metallic fouling, but it should form a most perfect lubricant to ease the bullet through the bullet seat into the bore with the minimum deformation. After a large amount of experimental work, a satisfactory method of evenly and thinly tin-plating the bullets was developed at Frankford Arsenal, the bullets being electroplated by rumbling in quantities in large plating barrels. The process works perfectly in quantity production. The coating is from .0003 to .0005 inch thick, applied on the cupro-nickel jacket. A coating of .0005 inch will not only entirely prevent metallic fouling, but will also remove this fouling from badly fouled barrels. A coating .0003 inch thick prevents metal fouling in good smooth barrels only, but is much more accurate than the .0005 inch coating.

The theory that tin would act as a lubricant in easing the bullet into the bore, and thus prevent deformation, was borne out in practice, because as soon as we began to shoot these bullets we at once got much better accuracy. It was then that we began to really find out something about small arms bullets. Formerly the various defects together made an inaccuracy so large that nothing could positively be determined, but now the various defects began to stand out alone. For example, we found that we made a decided gain in accuracy by slightly increasing the overall length of the cartridge, not seating the bullet quite so deeply in the case so that the ogive of the bullet extended through the bullet seat into positive contact with the lands of the rifling. We found that the bullets were being pinched in the bore so that the lead core extruded to the rear, making the base of the bullet untrue, and causing a deflection at the muzzle. Making the base slightly hollow corrected this error and gave us still another gain in accuracy. We found that a bullet smaller than groove diameter had to be made with a soft core and thin jacket so as to expand to fill the bore completely, but that a hard bullet of exactly groove diameter did the best work.

We then approached the powder question. In order to produce an ammunition which would be least deflected by wind, we wished to use a 170-grain bullet and deliver it at a muzzle velocity of at least 2,700 feet per second. It was not possible to get this velocity with the standard Pyro D. G. powder and remain within the limit of permissible pressures. Also, to obtain the accuracy we were looking for we wished a smaller variation in velocity than we had been able to obtain from Pyro powder. The new powder should burn very cool so as not to increase erosion, and it should give no excessive or corrosive fouling. A "progressive burning" nitrocellulose propellant was desirable to give the required velocity within the usual limits of pressure, using the 170-grain bullet for match ammunition. We have a new nitrocellulose powder surface-treated with a deterrent, in order to reduce the initial rate of burning, and hence the rate of rise of pressure. The powder grains are in such physical condition as to insure rapid and complete combustion of the interior portion of the powder grains. The older surface-treated powders were more difficult to ignite than the service propellant, "Pyro D. G." The new experimental powder is a progressive burning powder that is as easy and uniform of ignition as the service powder. The individual grains are of such uniformity as to give very even combustion, producing uniform velocities and pressures. The composition remains essentially the same as the older powder, the improvement in ease of ignition and uniformity of combustion being due to physical conditions rather than to change in composition.

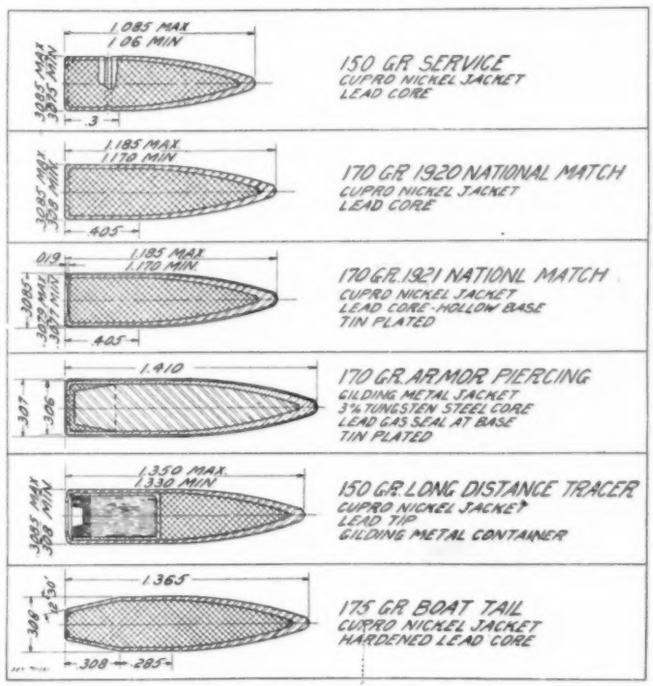
Finally, combining all the knowledge gained from our experimental work, we evolved what has since become known as 1921 National Match Ammunition. This cartridge might be termed a refined type of service ball ammunition, although it is perfectly practicable to manufacture it under quantity production conditions and at low cost. The case is of rather hard anneal to give perfect functioning in the rifle. The primer is the standard Frankford Arsenal No. 70, non-fulminate. The charge is 48.5 grains of DuPont EX-1076 powder, giving a muzzle velocity of 2725 f.s. to the 170-grain bullet with a breech pressure of 51,000 pounds. The bullet is tin plated, and is rather fully described in the illustration. This ammunition has been most successful. It was given a thorough trial at the National Matches this year by fifteen hundred of our most skilled marksmen, where it made a most remarkable showing. Every shooting record was broken, the ammunition showing itself capable of shooting continuously into the bull's eye at all ranges as long as the rifleman continued to hold, aim, and squeeze correctly. In fact the number of consecutive bull's eyes depended only on the endurance of the rifleman. Practically speaking this ammunition will shoot steadily into a 7-inch circle at 600 yards, or a 16-inch circle at 1,000 yards. It is far more accurate than any machine-made ammunition ever before manufactured anywhere, and is fully the equal of any hand-loaded, laboratory-made ammunition ever produced. It is so little affected by the wind that almost all the elaborate "wind doping" that the successful rifleman had to resort to has been relegated to the past. A change in wind which would move the old 150-grain service bullet out for a "three" at 1,000 yards will not take this 1921 bullet out

of the bull's eye. The ammunition causes no metallic fouling in good smooth barrels, and so long as the rifleman cares for his barrel perfectly he will have no trouble from fouling, and the use of ammonia will be unnecessary. But in rough bores it does give a little metal fouling, the rough lands apparently cutting through the thin tin plating which is only .0003-inch thick. For service ammunition this plating should be increased to .0005-inch thick, and this would entirely prevent metal fouling in all rifles, and would only very slightly decrease the accuracy.

But there always seems to be some "fly in the ointment." It has been found that with this ammunition something akin to mechanical soldering takes place between the bullet and the neck of the cartridge case. With the ordinary cupro-nickel jacketed bullet it requires a pull of about seventy-five pounds to extract the bullet from the case, but with the 1921 ammunition it requires about seven hundred pounds pull to extract the bullet. Ordinarily this causes no trouble because when the pressure begins to rise the case first expands to fit the chamber, thus freeing the bullet before the latter starts forward. However, it often happens in service that new rifles may be issued practically on the firing line where facilities are not always at hand to completely remove all rust-inhibiting grease from the bore and particularly the chamber. If this ammunition be fired in a heavily greased chamber the case cannot expand to free the bullet, and the high bullet pull causes a very high pressure. If the case be soft, as is often found particularly with war time brass, the case may give way, permitting gas to escape to the rear, wrecking the breech action, and perhaps injuring the firer. No way has been found to eliminate this mechanical soldering of the case and bullet. Shellacing the neck of the case decreases the bullet pull, but not to a sufficient degree. As a consequence we are hardly yet prepared to state that this is a perfect service ammunition, although it certainly does perform most excellently for instruction use in time of peace.

Machine Gun Ammunition

At present the service machine gun ammunition is the regular 150-grain service ball cartridge having a muzzle velocity of 2,700 feet per second. But this is far from satisfactory to the machine gunner. Its extreme range is only 3,300 yards, and it lacks destructive power at long range. The trajectory is too high, and the effect of lateral winds is too great. The Infantry Board have indicated that they desire the longest range and flattest trajectory possible. It had already been determined by Major Wilhelm at the Small Arms Ballistic Stations at Miami and Daytona, Florida, that these desired characteristics could only be obtained by using a heavy boat-tail bullet. Difficulty has been encountered in obtaining such a bullet that will be both reliable and accurate, but experimental work has now progressed to such an extent that it is possible to predict success in the very near future, and to indicate the nature of such a bullet. An enormous amount of experimental firing has been done. As to weight and form of bullet, the best results have been obtained from bullets weighing 175 grains. Such a bullet must be full groove diameter, and must be as hard and stiff as possible to resist deformation. The powerful gases, funnelled to the sides of the bullet by the taper of the boat-tail, seem to cut past this bullet to a much greater extent than with a flat-base bullet, and they decrease its diameter and deform it. Moreover, this gas cutting is the chief, and almost the only, cause of erosion in small arms, and as erosion is a very serious factor in machine guns, it must be eliminated as far as possible by a hard, tight fitting bullet. Metal fouling is here not so serious because the size of the personnel as compared with the number of weapons in a machine gun company is such as to permit the detail of experienced men to clean the barrels free from metal fouling between each firing. Another cause of inaccuracy with boat-tail bullets is difficult to eliminate. It is difficult to deliver such a bullet perfectly from the light barrel of a rifle or machine gun. The barrel vibrates very rapidly during the delivery, and the movement of the muzzle during vibration causes one side of the muzzle to drag slightly along the boat tail as the bullet departs from the muzzle, thus practically always tipping the bullet slightly as it departs from the muzzle. This tipping does not occur when the boat-tail bullet is fired from a heavy



Caliber .30 Bullets Developed at Frankford Arsenal

pressure barrel which has an outside diameter of 1.25 inches from breech to muzzle because such a barrel vibrates very little. Excellent accuracy has been obtained from boat-tail bullets in pressure barrels.

Erosion is an important feature in machine gun ammunition, not only from the standpoint of economy, but because a barrel throws a large proportion of short shots when worn out, and our barrels should last through a long barrage without endangering the advancing infantry. To decrease erosion we must both eliminate gas cutting as much as possible, and decrease the heat of the powder gases. Therefore it is not only a bullet problem, but a powder matter as well. A powder has recently been developed which has very cool gas, little flash, and which gives the required velocity of 2600 f.s. with a pressure of only 44,000 pounds.

Thus it will be seen that our experiments in this direction have progressed to such an extent that we can predict that in a very short time we will be able to give the machine gunners just what they wish.

At present the cartridge case of the service ammunition is manufactured so that theoretically it will function as well in the service rifle as in the machine gun, but this "compromise" case gives failures in both. A cartridge case for use in a rifle should be rather hard to prevent extraction troubles. Such a hard case when used in a machine gun is very apt to rupture. It will probably become

necessary therefore to make two types of cartridge cases, one for use in the rifle only and the other for machine gun only.

Armor-Piercing Ammunition

Prior to 1914 apparently very little interest was taken in armor-piercing ammunition. The matter was taken up in 1915 and eventually an armor-piercing bullet containing a steel core was made. This bullet, however, for lubrication purposes, had a soft lead nose. Several hundred thousand of these bullets were sent to France after the United States entered the war, but under instructions from the A. E. F. the manufacture of this bullet was discontinued on account of the soft nose. Further experiments were made and finally the model 1918 armor-piercing bullet was developed and put into quantity production. This bullet is composed of an alloy steel core weighing 65 grains, which is enclosed in a lead envelope, which in turn is enclosed in a cupro-nickel jacket, the ogive being the same as that of the caliber .30 model 1906. As improvements were made in armor plate, it was found that this bullet was not effective and a great deal of development work was done in an effort to obtain a satisfactory bullet.

The greatest possible velocity within the permissible pressure is the most important factor in the functioning of armor-piercing ammunition against armor plate. An armor-piercing bullet is limited as to its overall length and length of bearing surface for velocity and pressure reasons, to say nothing of friction and fouling. Numerous experiments with many different types have been made, but for accuracy and penetration, the bullet shown in the illustration is superior to the others. The ogive of the core of this bullet corresponds to the interior curve of the jacket and therefore requires no lead in the point, a feature hitherto universal in all recognized types. It is thought from an examination of plates struck with bullets having the lead points that the lead becomes liquid on striking and under high pressure practically blows the bullet to pieces and the core does not obtain the lubricating advantage from the jacket to aid it in its penetration of the plate. Such bullets also give much better accuracy than those having lead envelopes, because in manufacture it is extremely difficult to get the core in exact center of the bullet, and the walls of envelope and jacket of equal thickness. Lead envelope bullets are liable to be unbalanced, the center of gravity and center of form not coinciding, and all semblance of accuracy absent.

The accuracy at six hundred yards is really wonderful for ammunition of this character. It fully equals the accuracy of the service ammunition. With the high velocity that we are able to obtain with the new powders, it has tremendous penetrating powers. At 260 feet this bullet will penetrate chrome carbon armor plate .6-inch thick and at 600 yards it gave 90 per cent clean penetrations on a Schneider formula plate .25-inch thick. There is an instance on record of this bullet having penetrated an extremely tough piece of armor plate .3-inch thick at the extreme range of 800 yards.

Caliber .30 Tracer Ammunition

The bullet used in this type of ammunition prior to recent developments was practically a fac-simile of the British design. It weighed 150 grains and consisted of a cupro-nickel jacket, a lead tip and a gilding metal cup about .80-inch long, in which cup was compressed 30 grains of the tracer composition, consisting of 17 parts of barium peroxide and 2 parts of magnesium under a pressure of about 68,000 lbs. per sq. inch; the base of the bullet was crimped over so as to hold all of the components rigidly. This ammunition functioned perfectly in the machine gun, giving a brilliant white trace for about 600 yards, and was used exclusively by the Air Service during the War.

Since then it has been requested by the Infantry Service to develop a tracer for use in the rifle, giving fairly good accuracy at 600 yards, with a trace of at least 800 yards, becoming visible to the firer at not to exceed 100 yards from the rifle, in two types, having two different colored traces. Tracer bullets, for use in the machine gun, were wanted that would trace at least 1200 yards; no great stress was laid on accuracy. We desired to accomplish these requests by developing one type of tracer, i.e., one which would trace at least 1,200 yards, functioning equally well in rifle and machine gun, and at the same time meet the other requirements. Such a bullet would also satisfy the wants of the Air Service.

In carrying on the experimental work, the desire to use domestic ingredients as much as possible was always kept in mind. We realized that in order to meet the ballistic requirements, the tracer composition should occupy as little space as possible and at the same time have a light weight before burning, with a high ash content so that the loss in weight during the flight of the bullet would be low. This would also tend to shorten the bullet and thereby cut down the excessive metal fouling. In the early experiments a bullet was used which contained a cup .75-inch long and an inside diameter of .21-inch. A tracer composition was developed which weighed 15 grains when compressed into the cup, instead of 30 grains as used in the war tracer; this composition, however, needed an igniter to start it. When loaded by the war method, that is, compressing the mixture into the assembled components, unsatisfactory functioning was obtained. It then become necessary to load the cup first and afterward assemble it into a bullet with the other components. For a time very good results were obtained, then it was found that with the mixtures used and with the .75-inch cup, an extruding effect was obtained when the bullet went through the rifle barrel. After many experiments and firing tests, it was found that perfect functioning was assured when the container cup length did not exceed .56-inch. With the .75-inch cup traces exceeding 1,200 yards were obtained, but with the .56-inch cup traces of at least 1,000 yards were noted. Further experiments are under way to increase this trace with these components. The composition with the igniter charge for this type weighs 12 grains and has a high ash content. Satisfactory traces are obtained both in the rifle and the machine gun. Mixtures have been developed which give a white and red trace. Fairly good accuracy has been obtained and a charge has been established with an anti-fouling powder to group this ammunition with the 150-grain service bullet at 800 yards; it is noted that to obtain this the muzzle velocity of the tracer is much lower than the service bullet. With the shorter bullet and the anti-fouling propellant powder, metal fouling has been greatly eliminated. The visibility of the red tracer bullet is much greater than the white, particularly in daylight aganist the day.

While there will, undoubtedly, always be room for improvement in our small arms ammunition, as in all other ordnance material, it is believed that results obtained at the recent National Rifle Matches under the most strenuous competitive conditions abundantly justify the assertion that our American .30 caliber ammunition is, at least for the present, the best in the world.

Bombing the Alabama

By

W. B. HARDIGG

Member A. O. A.

ABOUT September 15th the Navy Department turned over to the Air Service of the Army the ex-battleship *Alabama* to be used as a target in bombing tests. The *Alabama* was a battleship of about 12,000 tons displacement, 368 feet long, 72 feet beam, and 23½ feet mean draught. She was built at Cramp's ship yard during the period 1896 to 1900. She had been capable of about 17 knots speed and carried as primary armament four 13-inch 35-caliber guns mounted in two turrets, one forward, the other aft; and in addition had fourteen 6-inch 40-caliber guns and several guns of smaller caliber.

The ex-*Alabama* was delivered almost intact by the Navy Department and was anchored in Tangier Sound, below the mouth of the Potomac River at a point some ten miles from Tangier Island and near the remains of the ex-*Indiana* and *San Marcos*, which had previously been used as targets by the Navy Department in various tests.

Ex-Indiana. Ex-Alabama Entirely Obscured by Smoke Screen from Four 100-pound Smoke Bombs

Programs of tests to be conducted against the ex-*Alabama* were drawn up entirely by the Army. Since the tests conducted during June and July off the Virginia capes with surrendered German vessels as targets had given information relative to the effects of large capacity, high explosive bombs, the principal purposes of the tests against the *Alabama* were to determine the effects of armor-piercing bombs, and chemical agents loaded in bombs, to demonstrate the possibilities of night attack, the usefulness of flares, etc., and to obtain further data on aerial tactics using light and heavy demolition bombs. The tests were conducted during the period of September 23d to 26th inclusive.

The first phase of the tests began on the morning of September 23d, when two Martin bombers dropped salvos of Navy type floating smoke bombs, which on water impact emitted smoke for several minutes; the smoke drifting down wind toward and over the target obscured the target from the observers' boat.

A few moments later two DH-4B planes flew over and dropped 25-lb. phosphorous smoke bombs on the target. These bombs exploded on impact and spread their flaming contents over considerable areas of the ship's deck and superstructure, causing dense clouds of smoke over the target.

In the next phase, 25-lb. tear gas bombs were dropped by the Martin bombers. After several direct hits had been made, observing parties went aboard and examined the effects produced. Gas masks were provided, thus permitting a detailed examination to be made. Without the masks portions of the ship were intolerable on account of the effect of the gas on the eyes.

The next attack made was with the 100-lb. phosphorous smoke bomb dropped from Martin bombers. The first salvo dropped consisted of four bombs; all registered hits. The smoke and fire effects of this salvo were most spectacular, as is apparent from the accompanying illustration. The ship was completely enveloped in smoke.

The next phase was a repetition of the 25-lb. smoke bomb attack, followed by the dropping of 50-lb. tear gas bombs. During the inspection after this attack the observers contaminated their clothing so that for several hours after their visit tears were shed whenever they gathered in a closed space. The eating and serving of meals became something of an ordeal.

The next attack was carried out just before midnight, DH-4B and Martin Bomber planes being used. The lighter planes used flares for illuminating the target area and later the bombing planes came over the target and dropped 300-lb. demolition bombs. In this attack one plane made two direct hits with 300-lb. demolition bombs. The effect of the burst was unusually spectacular. Red-hot fragments showered the ship from stem to stern and rose to a great height above her. Fires broke out forward, aft and amidships.

The first phase on the next day consisted in laying a smoke screen with the floating smoke bombs with DH-4B planes. This was followed by an attack by SE-5 pursuit planes with light bombs and machine gun fire. The planes approached the target at a considerable height, dived at the target with machine guns in action, levelled off, dropped their bombs and zoomed. A good percentage of hits was made, both with bombs and gun fire.

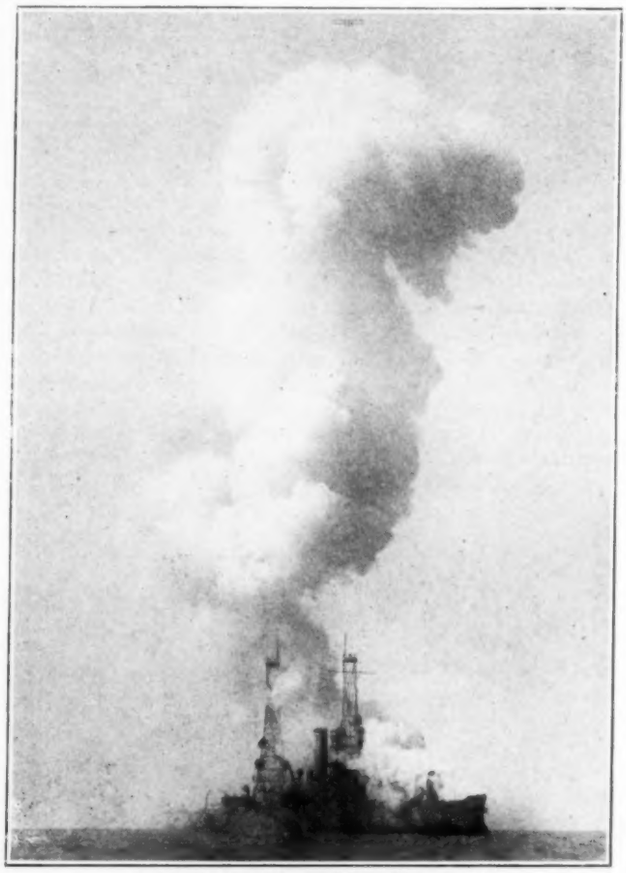
In the next phase 300-lb. demolition bombs were dropped by Martin bombers. Remarkable results were obtained with these bombs. Two bombs hit a short distance from the stem of the ship and raised the forward portion of the decking so that it masked the guns of the forward turret and also parted the anchor chain, setting the target adrift.

The next attack was with armor-piercing bombs dropped

from a great height by Martin bombers. No direct hits were made in this attack, and unfavorable weather caused a suspension of further attacks until September 26th.

On the morning of the 26th seven Martin bombers approached the target, carrying 1,100-lb. and 2,000-lb. bombs. The planes carrying 2,000-lb. bombs attacked first. The first bomb hit amidships close alongside, and in less than one minute the ex-*Alabama* had taken a decided list to port and was resting on the bottom in about 30 feet of water. The accompanying illustration shows the burst of the 2,000-lb. bomb alongside.

The remaining bombs were dropped on or near the target which rested on the bottom. The last illustration shows the smoke drifting from the impact of an 1,100-lb. bomb which carried away the smoke stacks and caused the forward mast to collapse. The tests conducted have given valuable information to the War Department, which will be used in design and development of munitions.



Direct Hit with 300-pound Demolition Bomb
Note Bombing Plane Above. Smoke Column and Forward Decking Blown Upward so as to Mask Fire of Forward Turret

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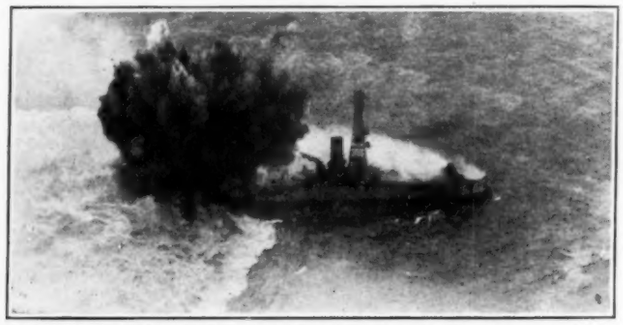
Rear Admiral W. F. Fullam, retired, has said of the sinking of the battleship *Alabama* by army Martin bombers on September 26, 1920: "It is childish to attempt to discount this result by saying the *Alabama* was an old ship. No modern dreadnought could have survived the attack."

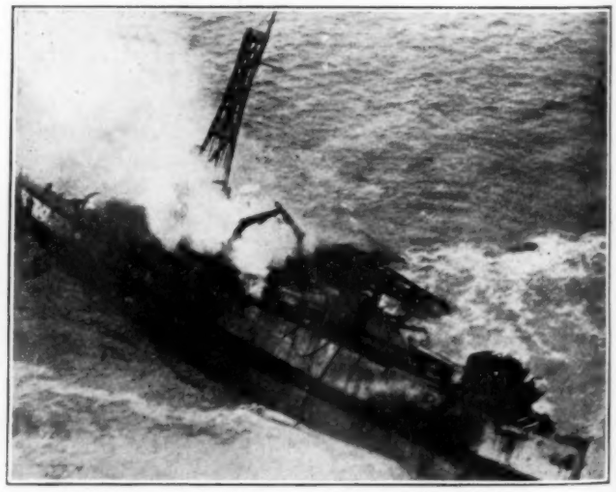
The revolution of "our present conception of sea warfare and strategy" (to quote from the naval notes of the British Admiralty) having occurred, there was a lively interest in what would be found about aviation in the proposal of the United States for a limitation of naval armaments. It was very little, merely this: "The limitation of naval aircraft is not proposed." The following note was appended: "Owing to the fact that naval aircraft may be readily adapted from special types of commercial aircraft, it is not considered practicable to prescribe limits for naval warfare." But it was recommended that the total tonnage of airplane carriers shall be as follows: United States; 80,000 tons; Great Britain, 80,000 tons; Japan, 48,000 tons." So an attempt was made to limit the number of planes that could be used as auxiliaries to the fleets of the three sea powers.

If Sir Percy Scott and General William Mitchell are right about the menace of the bombing airplane, the nation that possessed a marked superiority in commercial aircraft over other nations could become, if it manufactured explosives on a large scale, the most formidable sea power, provided it quickly improvised swift airplane carriers. The nation that neglected commercial aviation would do so at its peril. Probably more advanced in the use of aircraft for transportation than any other country is Germany, in spite of the inhibitions and safeguards of the Treaty of Versailles. * * * Both France and England have a considerable superiority over the United States in commercial aviation. Japan lags in competition, but aims to excel.

The United States has not only been slow to manufacture airplanes for commercial purposes, but has been backward in providing the navy with fast carriers. Obviously for its own interests the problem of limiting naval aircraft should be grappled with at the Washington conference.—Editorial, "The Aircraft Problem," *New York Times*, November 15, 1921.



Detonation of 2,000-lb. Bomb, Sending Target to Bottom in Less than 1 Min.



The Alabama as She Appeared at the Completion of the Tests

Anti-Aircraft Machine Gunnery

By

S. G. GREEN

Member A. O. A.

THE application of artillery to anti-aircraft use was discussed in detail in an article by Dr. R. L. Goetzenberger in the May-June, 1921, number of ARMY ORDNANCE. Inasmuch as the tactical use of machine guns and automatic rifles for anti-aircraft purposes is, of necessity, a different problem than that of anti-aircraft artillery, it is intended to set forth in this article the general uses of small arms anti-aircraft matériel during the World War and the progressive development of this matériel to the present date.

Anti-aircraft fire of artillery is directed almost exclusively by indirect fire methods; that is, by utilizing firing data which has been obtained from independent sources such as range finders, fuse indicators, sound-ranging apparatus, altimeters, and combination correctors which automatically compensate for the different altitudes and consequent ranges. By means of mechanical scales, the results are read off direct and applied to the elevation and traverse scales of the gun. The gun is then set in accordance with this firing data, and fired in a manner similar to Coast Artillery methods of fire at given time intervals. This method of fire is necessitated by the weight and size of the gun, which renders it less flexible than would be the case with a shotgun being fired at clay pigeons or game. With small arms anti-aircraft weapons, the problem is more nearly similar to game shooting with the bird flying at different angles and at different positions with respect to the gunner. In such firing the weapon is used entirely as a direct-fire weapon similar to the ordinary rifle. The problems that confront the anti-aircraft artillery are also present and must consequently be compensated for to gain the same results. The small-arms matériel is of sufficiently light weight and is sufficiently flexible to permit the gun to be fired in much the same way as the ordinary shotgun would be fired from a fence post as a rest to steady the weapon. The development of anti-aircraft matériel during the World War was carried out along the same lines for artillery and small arms anti-aircraft, both in guns and mounts; consequently the machine guns and automatic rifles were mounted in the same way; that is, mounted to gain traverse and elevation in only two planes.

The mounts for small arms anti-aircraft weapons developed during the World War were made up with an adapter head with a pintle at the lower part of the bracket, which revolved freely in the tripod head. The upper part of the bracket was provided with a U-shaped opening in which was mounted the machine gun or automatic rifle. This made it possible for the gun to be elevated or depressed about the axis pin of the gun, and to be traversed by rotating the mount adapter in which the gun is mounted about the pintle. The machine gun mounted in this fashion was equipped with a shoulder stock and anti-aircraft sights. This type of small arms anti-aircraft mount was used during the World War by the Allies and by the enemy. The mount adapters were so arranged that they could be detached from the tripods and the pintle mounted on a post in which had been drilled a proper hole to take the pintle. Similar adapters were provided for attachment to the ordinary Infantry tripod.

With these adapters the gun could be elevated between 25° depression and 85° elevation. Orders were placed in this country for the manufacture of this anti-aircraft matériel, and a considerable quantity was completed before the signing of the Armistice.

After a program had been worked out for the manufacture of the anti-aircraft small-arms matériel developed during the war, considerable study was given to the possibilities of developing more efficient small arms anti-aircraft matériel by the Small Arms Division. The development of a suitable training device for training anti-aircraft gunners in the use of anti-aircraft sights was undertaken during the World War. After the signing of the Armistice, the original development was temporarily held up for the purpose of making a complete study of the design of all anti-aircraft matériel. As a result of this study, the original program for the development of the training device was completely revised and a new design of training device was undertaken.

Fig. 1—Browning Machine Gun on Anti-Aircraft Mount

Training Device for Anti-Aircraft Gunners

The training device developed for the training of anti-aircraft gunners in the use of anti-aircraft sights for small arms consists of a target-frame attachment mounted on the regular anti-aircraft tripod in such a manner as to present an artificial target of sufficient dimensions to cover the field

of any ordinary actual target for anti-aircraft gunners. The framework carrying this target is pivoted about the same pintle as the gun adapter, so that the target can be presented to the gunner at an angle, both in traverse and in elevation. Elevation is accomplished by pivoting the framework of the target on trunnions, the axis of which passes through the center line of the trunnions of the gun. The target is laid off in squares, which are to scale, and in proportion to the actual target field of the sights to be used. Upon the back of the target frame is mounted a double pantograph, the lower point of which is pivoted on a fixed pivot of the target frame. The target and target indicator sheet are carried at the top corner diagonally from the pivoting point of the pantograph.

Fig. 2—Using Hotchkiss Machine Gun on Tripod Against Enemy Aircraft in France

At the center of the pantograph is mounted a motor which is geared to a rack in such a way as to cause the pantograph to be driven in a predetermined path at a given rate across the field of the target sheet. The target proper consists of a miniature airplane mounted on the frame of the target recording sheet at a proportionate distance above the axis of the gun to offset the distance between the axis of the gun and the axis of the sight. The sight indicator is pivoted about the point on which the target is mounted to readily show the point at which the projectile should hit. The sight indicator consists of a sight form made of xylonite, which is proportional to the anti-aircraft front area sight, the center of which is the same distance below the target as the distance from the center of the front sight to the axis of the gun. In this way the projection of the sight can be readily outlined on the target indicator sheet to show the point at which the gunner should aim, to show the point at which the projectile actually pierced the target indicator sheet, and the variation and error in sighting. The target recording sheet consists of a piece of vellum paper carried in the target recording frame. The target recording frame is provided with a back stop, which is faced with cork to support the target sheet. A target rod similar to the Hollifield Target Rod is used to pierce the target recording sheet and the target sheet.

After a shot is made, the target recording frame is brought back to position until the hole pierced in the target recording sheet coincides with the hole pierced in the target sheet. While in this position the sight indicator is dropped in a vertical position so that the center of the sight indicator is in the same position on the target indicator sheet as the axis of the bore should have been at the time the shot was made. The contour of the sight indicator which is made in proportion to the front sight shows where the shot should have been made. The actual error in sighting can be marked off by noting the point at which the target should have been pierced and the point at which the target was actually pierced. In order to know definitely the point which should have been pierced, the movements of the target are governed by setting the pantograph for a given angle of travel, either upward or downward across the target sheet as desired. When the sight indicator has been brought in position, lines are drawn from the center of the sight indicator and the point on the contour of the sight at which the gunner should have been aiming and from the center of the sight indicator to the point actually pierced by a given shot. These two lines will show the amount the sighting was in error both in leading the target and the estimation of the angle the target is presented to the gunner.

The training device for anti-aircraft machine gunners demonstrates conclusively the defects of the anti-aircraft mounts which carry two parallel guns and in which only two dimensions for control are provided. It was found that following the target with direct-fire methods, using the two-dimension type of mount, made it practically impossible to offset for elevation and deflection for a traveling target, inasmuch as the corrections when plotted showed a step-by-step curve rather than a comparatively straight line. Corrections with the two-dimension mount are made, first in elevation and then in traverse, as a

Fig. 3—Training Device for Anti-aircraft Machine Gunnery

This mechanism, invented by Capt. S. G. Green, the present Chief of the Machine Gun and Rifle Section, Small Arms Division, Ordnance Office, although in use but a relatively short time, has pointed out certain errors in anti-aircraft machine gunnery practices during the World War, and also the ways and means whereby they may be corrected.

combination correction would necessitate a mount provided with flexibility in three dimensions. It was also found that a mount designed to accomplish the flexibility in three planes would be unsuitable, unless the guns could be held in a vertical position; that is, the sides of the receiver of the gun should always be parallel with a vertical plane through the axis of the bore. This is necessary inasmuch as the sights would be in error if the guns were allowed to cant to gain the three-dimension flexibility required. With a view to overcoming these defects, specifications were drawn up for the design and development of suitable adapters for mounting the gun in such a way as to provide 360° traverse and elevation between 25° depression and 85° elevation.

A semi-ball mount was developed at Springfield Armory under the direction of Col. Julian S. Hatcher, of the Ordnance Department, in collaboration with the Small Arms Division, Machine Gun and Automatic Rifle Design Section, to give a three-dimension flexibility and at the same time to limit the universal of the ball mount by allowing the post of the ball mount to operate in the slot in the ball housing upon which the gun is mounted. It is found desirable to mount more than one gun on a given adapter for increasing the volume of fire. The Ordnance Department developed a multiple mount for mounting two Browning machine rifles (a Browning automatic rifle with heavy barrel with annular rings which cools the rifle sufficiently to gain a more sustained fire) or two Browning machine guns. In studying tripod design during the World War, it was found that the mounts as designed were too cumbersome to put into action and were deficient in that they could not be erected in a trench or shell crater, and were very difficult to set up. The development of a more suitable tripod in connection with the development of the multiple mounts was also undertaken. The present mount, with the semi-ball mount adapter designed and developed by the Small Arms Division and Springfield Armory, has been given preliminary test. The functioning of these mounts has demonstrated that the mounts are far superior to the wartime matériel and should make it possible to deliver anti-aircraft fire far superior to that delivered during the World War with the mounts that were not adapted for this work.

Fig. 4—Anti-Aircraft Adapter for Infantry Machine Gun Tripods, with Browning Machine Gun, Trench Sight, Expendable Ammunition Box and Cartridge Belt Guide

Anti-aircraft sights of the "front area" type, to be used in the front lines and for instant use where considerable time is not available for adjustment and range finding, have been developed for use with the multiple mounts. The range for which these sights are designed is approximately 500 yards. "Rear area" sights, designed for ranges between 500 yards and 1,000 yards, which are more elaborate than the "front area" sights, and for use in the rear areas where more time is available for adjustments, range finding, etc., are also provided for the multiple mount. The sights may be mounted either on the side bracket or upon the gun direct.

The effective range of the caliber .30 machine gun renders this type of anti-aircraft defense or offense of very limited use, inasmuch as the caliber .30 ammunition is only effective against personnel and low-flying unarmored planes, such as scout planes, etc. During the war no special small arms weapons were designed specifically for anti-aircraft purposes. The Small Arms Division has under development a .50-caliber machine gun which is being designed strictly for anti-aircraft purposes. This gun will be air-cooled and mounted either upon trunnions or through a gun pin hole similar to the Browning machine gun. The trunnions are designed so that the point of mounting will be in the line of action of the gun in order to get a well-balanced weapon. The gun is to be mounted on a semi-ball mount on tripod of the general design of the multiple mount for mounting two Browning machine rifles or two Browning machine guns. The tripod mount for mounting the Browning machine rifle or the caliber .50 anti-aircraft machine gun will weigh approximately sixty pounds. The tripod can be readily set up, as the mount can be folded similar to an umbrella, and once set up, is ready for instant use.

(To be continued)

Springfield Armory Experimental Department

By

JULIAN S. HATCHER

Member A. O. A.

DURING War days the inhabitants of Springfield, Massachusetts, found a subject for discussion in certain peculiar building operations that were visible beyond the iron fence around the Armory. The fact that a new building of modest size was being erected was no particular cause for comment, but the location of the building was a little unusual, for it was being built on a steep terrace, so that from the upper side the building appeared to be one story high, while the other view showed three stories. Another, and still greater peculiarity, lay in the fact that from the west end of the new building a long low concrete structure was being extended along the terrace for a distance of no less than 600 feet.

Should the same observer who puzzled his brain over these things have had an opportunity to visit the new building a year later, this is what he would see, after entering the building by the main doorway on top of the terrace, and being greeted by the sign, "Experimental Department and Small Arms Proving Ground."

The New Experimental Building at Springfield Armory

On the right he would find the office of the Officer in Charge. This room contains a small but complete library on firearms, and in racks along the wall are numerous different weapons, selected to represent the principal classes of gun mechanism. At the opposite end of the hall is a room, kept carefully locked, which contains a collection of automatic arms ranging in size from a 1-inch cannon down to a .22 caliber rifle and comprising the important types of automatic firearms of nearly every country in the world. Next to this room is a photographic laboratory equipped for doing all classes of work from pass photos to motion pictures. On this floor there is also a room equipped with loading machines, powder scales, etc., for making up experimental ammunition. In addition, this room contains ingenious machines for determining the important features of ammunition submitted to the Small Arms Proving Ground for examination. Among the quantities determined in this room are the weight and diameter of the bullet, the weight of the powder charge, the gaging of cartridges for size, the bullet pull, and the hardness of the brass, all of which are factors vitally affecting the performance of ammunition, especially in machine guns. Other rooms on this floor which are of less interest are a drafting room where new designs are made up, a loading room where ammunition is loaded into machine gun belts incidental to testing either the ammunition or the machine guns, and a room where results of tests are recorded by a clerical force.

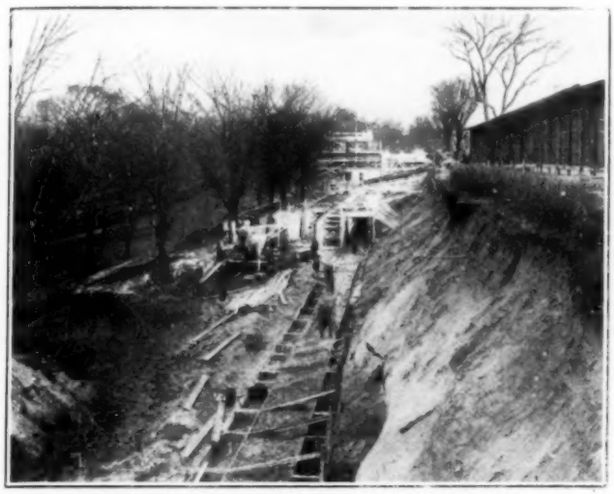
The next floor below this contains a small machine shop or model room for making up experimental arms or devices and a storage room where guns, ammunition, etc., are kept.

On the lowest floor of all, which is entirely beneath the level of the terraces, are a number of rooms which are built sound-proof and are provided on the side next to the terrace with holes through which guns may be fired. The bullets go directly into the side of the hill so that there is no danger of their ever getting out to do damage. One of these rooms is fitted up with a work bench so that inventors submitting devices may make what tests and adjustments they desire without being disturbed by outside interference or being required to expose confidential devices to observation. The room next to this is fitted up with two very ingenious machines. One of them is designed for testing ammunition for hangfires. The ammunition is fired at regular intervals through a revolving disc and the exact amount of all the hangfires and delays in ignition can be determined accurately. Another machine contained in the same room is for testing the synchronization of aircraft guns. The gun is mounted on a stand in front of a rapidly revolving metallic disc, the speed of which is measured by an electric tachometer and can be varied at will. The gun is fired by a cam on the rotating shaft, using a regular aircraft trigger motor such as is installed on the latest airplanes for firing synchronized guns. This machine is made to take guns of all sizes up to the latest .50 caliber.

Another room, and the largest one on the floor, is the Machine Gun Proof Room. It is fitted up for making functioning and endurance tests of all kinds of machine guns and automatic rifles. An interesting feature is the arrangement for testing the functioning of synchronized aircraft guns. This consists of a stand for holding the gun and a regular aircraft firing gear driven at a uniform speed of 1,800 revolutions per minute by an electric motor.

The remaining room on this floor is the Rifle and Pistol Proof Room, which contains, besides space for firing endurance tests, several machines designed to measure the recoil of a rifle, the bolt lift or force required to open the gun, the extraction pull required to remove a fired cartridge case, etc.

Beyond this room is a lobby, in the west wall of which are shooting ports opening into the underground ranges extending along a terrace from the end of the building. There are three of these ranges, the longest being 680 feet



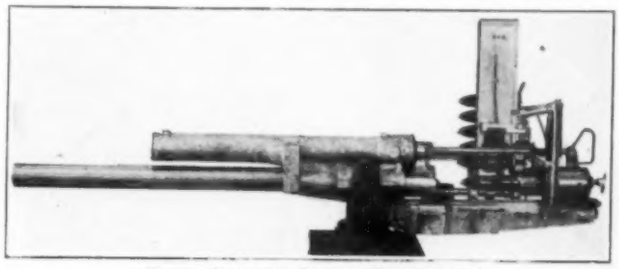
The 200-yard Underground Range During Construction

in length. This is the peculiar concrete structure referred to above which in its finished form is completely covered by the earth and is no longer visible from the outside. It provides a place where rifles can be targeted up to 200 metres without interference by wind or other disturbing influences. In addition to this long range there are two shorter ones, 180 and 150 feet long respectively. The 180-foot range is used for velocity testing, and contains the initial and terminal targets for the chronographs. The other range is used for taking pressures, for machine rest targets and for testing the erosion of machine gun barrels. In a small room off the lobby there is a concrete pier containing five Boulengé chronographs. The concrete pier containing the instruments is separated from the rest of the building so as to avoid interference by vibration.

During the war the most important activity of this establishment was the testing of small arms and ammunition produced by the various manufacturers, a function which is indicated by the name, Small Arms Proving Ground. The necessity for such an establishment was due to the fact that there were eight firms supplying ammunition, five supplying rifles and a large number of different firms supplying machine guns, automatic pistols and revolvers. The result was a wide variation in the quality and characteristics of the different products. For example, ammunition had to be divided into several grades, one grade suitable for aircraft machine guns; another grade suitable for use in ground type machine guns; a third type suitable for use in rifles only; and a fourth type so inaccurate as to be suitable only for training purposes. The grading of this ammunition was controlled by the inspectors at the various plants. Inspectors at the arms plants were responsible for the operating of the weapons so that they would function properly, but when there were so many new plants and so many different inspectors it was unavoidable that there should be serious differences in the products received from the various factories. For example, a plant manufacturing rifles might be supplied with a certain kind of ammunition with which the guns would function satisfactorily, but when they were used with a different ammunition they might not work at all. In order to effect such co-ordination as to bring about sufficient uniformity of product to meet the service needs, the Small Arms Proving Ground was required to test a small sample from each factory of each day's production of both arms and ammunition. In this way errors of manufacture were detected before they had become serious and many difficulties were straightened out.

Such an institution is an absolute necessity in time of war, when arms and ammunition are being produced by many different sources; but it is not essential in time of peace; and this activity of the establishment at Springfield ceased abruptly on the cancellation of the wartime contracts. Since that time the plant has continued on a gradually decreasing scale as an experimental laboratory for developing and testing new devices in the field of firearms and for improving existing ones.

Perhaps the most important function the Experimental Department has performed since the armistice is in providing a place where new designs submitted by inventors or manufacturers can be given an adequate test to determine their practicability and military value. It is a well known fact that an erroneous impression has grown up in the past that the Government is slow to take advantage of new developments. This impression finds expression in the oft-repeated stories in the newspapers and magazines of American inventions of great value that had to be taken to foreign nations to obtain recognition. In order to prevent this false impression from persisting in the future, it is absolutely essential that the Government should be prepared to promptly and thoroughly investigate all new inventions submitted to it. In the field of small arms the equipment of the Experimental Department is ideal for this purpose, and all that is necessary is to have a small but thoroughly trained personnel who will be able to make the required tests efficiently and judge the value of the device intelligently. One trouble in the past has been due to the very specialized field of knowledge of the Armory personnel on small arms subjects. Before the establishment of a separate Experimental Department, with an officer assigned solely on experimental work, this department was necessarily a side issue to the main and pressing business of making the Springfield rifle

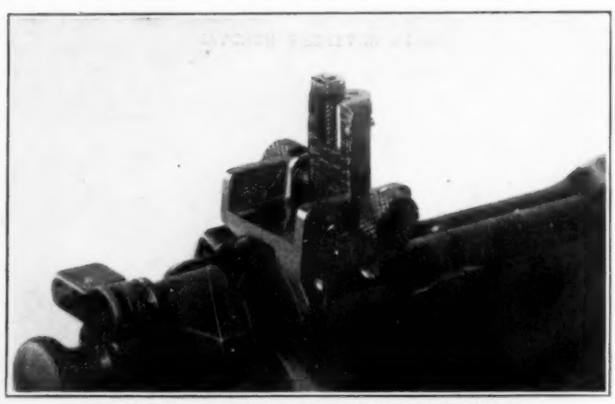


37-mm. Automatic Cannon, Experimental

as efficiently and cheaply as possible. As a result the Armory personnel became familiar with their own problem of manufacturing the Springfield, but through lack of opportunity attained very little familiarity with firearms in general. However, since the beginning of the war there has at all times been an officer specially assigned in charge of the Experimental Department. The various officers who have held this position have been assigned to it on account

of their interest in firearms in general, and as a result they have not limited their activities to the Springfield rifle and the Browning machine gun alone but have made a comprehensive study of all types of guns and have obtained and experimented with the leading commercial types of target and hunting arms, as well as with strictly military types. This enables them to handle intelligently any firearms problem and to reply with convincing intelligence to the vast number of interested citizens who constantly refer to the Armory for information on firearms topics of all kinds, and whose opinion of the Ordnance Department would correspondingly suffer if they should receive a reply indicating ignorance of any phase of the subject in hand, however remote it may be from Springfield's particular line. The satisfactory state of affairs that has existed in this matter since the war is a direct result of the Ordnance Department's newly adopted policy of specialization, which it is to be hoped can hold out in the future in spite of the insufficiency of personnel.

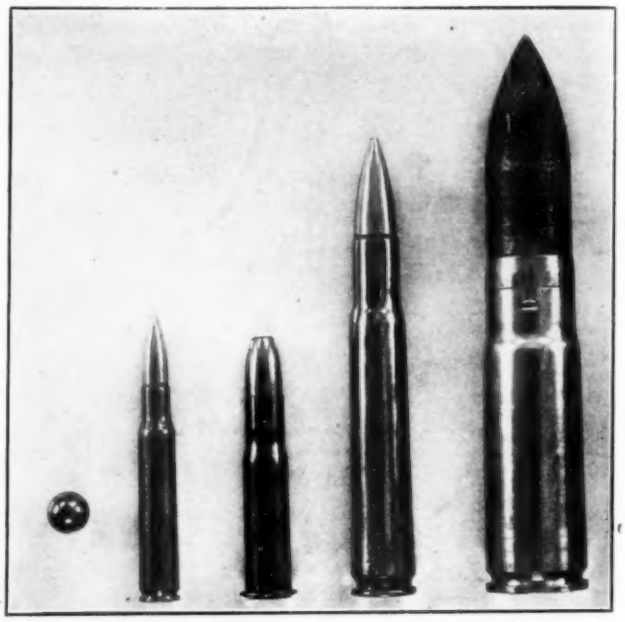
In addition to the tests of devices submitted by inventors, the Experimental Department has frequent occasion to make tests along small arms lines which are more or less purely scientific in their nature. In this class comes an examination of guns which have failed in service and a determination and subsequent correction of the causes of failure. A very spectacular achievement in this line was the elimination of bursting of Springfield rifles in service due to the failure of receivers or bolts. Prior to 1917 a certain number of rifles would burst each year. These accidents were generally due to excessive pressures occurring from one cause or another and were supposed to be unavoidable. In 1917 the Experimental Department of this Armory received several such rifles for examination. The report showed that while the failure was due primarily to defective ammunition it might have been prevented by better treatment of the steel in the receiver. When this fact was brought to the attention of Colonel (now General) W. S. Peirce, commanding the Armory, he at once instituted vigorous steps to improve the product in this regard. This he accomplished by the establishment of a double heat treatment which made the outside of the receiver hard and wear-resisting and left the inside in the form of a



New Receiver Sight (Experimental) for Springfield Rifle

tough tenacious core which effectively resists efforts at fracture. No rifle made since the establishment of this new heat treatment has burst in service through the failure of the receiver or bolt.

To show the character of the routine work that is continually being done by the Experimental Department in addition to designing and special tests, it may be mentioned that in the past few months we have investigated and reported on the relative cost of flour paste and the various prepared pastes for use on the target range; have made erosion tests of different kinds of steel with various heat treatments suggested by the Bureau of Standards in the hope of finding a material which will be more resistant to erosion than the present steel and will thus result in economy through longer wear for rifle and machine gun



Machine-gun Cartridges (left to right): Steel Bullet for Centrifugal Gun; .30-caliber Service Cartridge; 11-mm. Incendiary Ammunition; Cartridge for new .50-caliber Machine Gun; Cartridge, 25-mm. Automatic Gun.

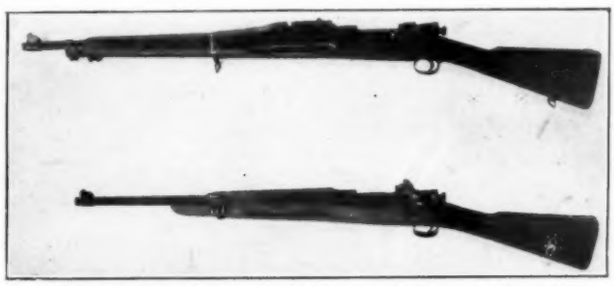
barrels; have tested different non-corrosive metals (including Monel Metal and the stainless steels) for making rifle barrels, in order to prevent the waste of rifles through rusting and corrosion from powder gases; have developed a solution for rifle barrels designed to protect them from corrosion or rusting, etc.

All such tests as these are of interest not only to the Government but to the American firearms industry at large and any advances made along these lines result in an economic gain to the nation.

Among the activities of the Experimental Department which have aroused the interest of firearms manufacturers is the development of an improved method of testing rifles and ammunition for accuracy. Prior to the war tests of this nature were conducted in a machine rest which clamped the rifle solidly in position. This device was notoriously cranky and the results depended more upon the skill of the operator than upon the accuracy either of the gun or ammunition. During the war the Experimental Department adopted a little known device of a civilian rifle experimenter, Doctor Mann. Through its adoption by Springfield Armory, the Mann rest has now become one of the recognized methods of testing ammunition for accuracy. In addition, the Ordnance Department went still further and built a new rest for holding the rifle in accuracy testing which eliminates all the uncertainties of the old method.

One of the main activities of the Experimental Department since the war is the attempt to overcome defects in our present material which the war brought to light. As machine guns were more or less in the process of development when the war started, this effort naturally was largely concerned with machine guns and subjects connected with them. One of the first large undertakings of this nature was to adapt the Browning machine gun to

aircraft use by strengthening the mechanism so as to allow a high rate of fire and by changing the firing mechanism so as to give perfect synchronization. After these changes were worked out satisfactorily, the Armory put the changes into effect by converting a number of the old guns, and the Experimental Department tested all of these guns on the synchronizing stand above referred to. Another development had to do with the construction of a satisfactory .50 caliber machine gun. In order to enable Frankford Arsenal to develop the ammunition for this gun, Springfield made up several testing guns by chambering captured German anti-tank guns for our own new ammunition. After the construction of the .50 caliber aircraft machine gun, the Experimental Department ran synchronizing tests on this weapon. The firing of such a large piece, indoors, involved several unforeseen difficulties. The blast of gas from the gun was so great that the muzzle was stuck through one of the firing ports so that the gas could be carried off by one of the exhaust fans. The very first shot blew the partition to pieces. The partition was replaced and was carefully shored up and braced in various directions but still kept falling down from time to time. In order to overcome such difficulties in future tests, the partition was rebuilt of steel.



.30-caliber Carbine, Experimental: Service Rifle Shown for Comparison

Another project which involved even greater difficulties in providing proper firing facilities indoors was the building of an automatic aircraft cannon firing 37-mm. projectiles. During the development of this gun it was fired over a thousand rounds in the Experimental building. While the arrangements for this firing were such that the projectiles were successfully taken care of with no danger to outsiders, there is always a certain element of danger to the personnel conducting firing tests of any kind. For example, in firing 37-mm. gun a cartridge exploded in the air through the faulty action of a poorly designed part of the mechanism. Fortunately the explosion caused no damage, and, needless to say, the new mechanism was so constructed that such an accident could not occur again. On various occasions the excessive heat generated when firing machine guns has led to premature explosions, especially in new and untried types of guns which must undergo their first tests here. Another occasional cause of inconvenience is the habit that even the best constructed backstops have of causing a bullet to rebound under certain conditions. While no harm has yet been done by any of these rebounding bullets some of them have capabilities of doing damage, as is evident from the fact that on two separate occasions bullets of this nature have passed through the clothing of the Experimental officer.

While almost all anticipated conditions of firing were provided for in building the Experimental Department, we have found one case that it is difficult to handle, even with all the facilities that can be thought of. This condition arose in the recent design of a new anti-aircraft machine gun mount. This mount was intended to be fired at all angles from the horizontal to the vertical. When the mount was first constructed it was tested out in the horizontal position and functioned correctly. This fact did not, however, give any assurance that the belt would feed properly when the gun was pointed straight up. As it was manifestly impossible to fire the gun vertically in the Experimental Building, the gun was taken to a shed some distance away. On the roof of the shed were laid two thicknesses of iron plates, which were then covered with sand, and the vertical firing was attempted. For the first few shots, nearly all of the bullets seemed to rebound from the iron plates, to the great discomfort of the gunner. However, after a few moments the absence of rebounding bullets was noticed. This suspicious fact caused an immediate investigation, which showed that the concentrated firing had drilled clean through the plates and that the bullets were proceeding unhindered on their way. For a time we were at a loss as to what course we should pursue to continue our test, which was very necessary, as some serious feeding difficulties had been encountered. At this juncture another post-war development came to our rescue: this was the device which has been developed by the Small Arms Division for firing blank cartridges in machine guns. We took the gun back to the Experimental Department and proceeded to load up several belts of blank cartridges and fire the gun vertically upwards in an ordinary room. As a result of this firing, we were able to overcome our difficulties and produce a satisfactory mount.

Experimental Browning Machine Rifle with Bipod

The improvement of service arms since the war has not been confined to machine guns. The rifle is perhaps the most important weapon in an army, and the war pointed out some improvements that could be made in ours. The most important work of this class has been the development of a receiver sight for the Springfield rifle. Our war experience with the 1917 rifle, which has a peep sight close to the eye, showed conclusively that this general type of sight is far superior to the service sight on the Springfield rifle, which is located on the barrel about ten inches from the eye. However, the 1917 sight is very unsatisfactory in one respect and that is the absence of a windage adjustment. Accordingly, at the request of the Infantry, the Ordnance Department undertook, first, to develop a suitable receiver sight for the Springfield, and, second, to modify the 1917 sight so as to include windage. This work was assigned to the Experimental Department. The placing of a receiver sight on the Springfield rifle proved to be a very difficult task because when the rifle was designed there was no space left on the receiver for such a sight. An ideal sight would be one which could be attached to the Springfield rifles now in service when they are returned to the Armory for cleaning and repair. Several models were designed and submitted to a preliminary examination by the using service, and as a result three models have been selected for further trial. At the present time 25 of each of these selected types of sight are being built and will shortly be tested by the Infantry. One of the most promising of the new sights is shown in the photograph.

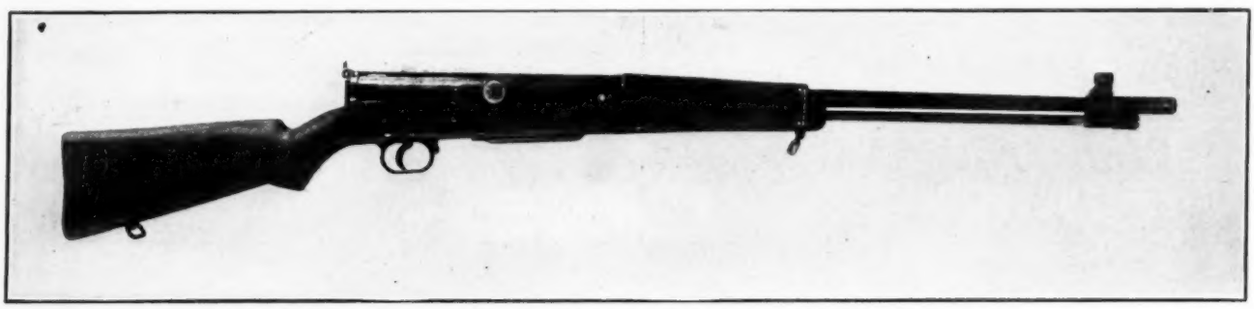
Another modification of the Springfield rifle is the addi-

tion of a pistol grip to the stock. A third change is the design of a new bayonet to meet conditions laid down by the Infantry School which is testing the new material.

While the Infantry is the main user of the service rifle it is not alone in constructive criticism, as the Cavalry suggested the production of a carbine for mounted work, a sample of which has already been sent out for test. Another requirement of the Cavalry had to do with the modification of the automatic rifle to give it greater fire power and steadiness of aim. In compliance with this requirement the Experimental Department developed and built a machine rifle which is simply a Browning Automatic rifle with a heavy barrel and a bipod added. This machine rifle can be fired 1,000 shots without cooling, whereas the ordinary automatic rifle can only fire about 300.

Still another class of development has to do with devices for training troops, the aim of these devices being to effect an ultimate economy along this line. One of these training devices is a special barrel to enable the .45 caliber automatic pistol to fire blank cartridges. If it can be successfully developed this will be of special benefit in training horses as it will prevent danger of injuring either animals or personnel through the accidental discharge of ball cartridges, which is likely to occur should a soldier be firing an automatic pistol on the back of a frightened horse. Another development affecting the automatic pistol is the production of a .22 caliber slide to replace the regular one. With this device the user of an automatic pistol can take off his regular barrel and slide and replace it in a few seconds with a new one without the aid of tools. He is then ready to use his .45 caliber automatic pistol to fire .22 caliber cartridges. Some of these attachments were built and sent out for trial. They were tested by the Cavalry and returned to Springfield with suggestions for improvements. The pistols are being changed to embody the suggestions, and will be tested again in the near future. The adoption of this device would effect a great economy in training, not only because of the greatly reduced cost of the ammunition but also because the .22 caliber cartridges make so much less noise and recoil that the recruit's defects in shooting can be more quickly overcome than when using the high powered cartridges which cause him to flinch and become gun shy. After he has once learned to use the pistol properly he can be shifted over to the high powered ammunition without noticing the change. A .22 caliber rifle has also been built which is the exact counterpart of the .30 caliber Springfield in size, weight and appearance.

Important as are the projects mentioned above, another of still greater magnitude has claimed the attention of the Experimental Department for the past several years. Unfortunately this project is also one involving grave difficulties and problems. It is the development of a semi-automatic shoulder rifle to weigh no more than the present Springfield rifle. For many years it has been recognized that such a production is the next step in firearms advancement. The great importance of a weapon of this nature is shown by the fact that during the war the Germans utilized a somewhat imperfect rifle of this kind which was made for another foreign nation. This gun did not even use the German caliber of ammunition, but in spite of this serious disadvantage the need for semi-automatic shoulder arm resulted in its employment. A weapon of this type does not require the soldier to perform the manual operations of turning up the bolt, drawing it back and ejecting the empty shell, pushing in a live shell and turning down the bolt again after each shot. One of the greatest difficulties in obtaining a rapid and accurate fire is the immense amount of training which must be gone through in order to enable a soldier to perform all these operations quickly enough to avoid losing the opportunity for a second shot and at the same time smoothly enough to avoid deranging his aim. Suppose that a soldier in action is able to locate an object to shoot at. In general it will be difficult to see because the enemy will expose no more of himself than is absolutely necessary and will use every effort to remain invisible. The soldier will then have a poor aiming mark and his first shot will very likely be a miss, and if he goes through all the operations of reloading his rifle he may not only take his eye from the object and thus lose sight of it, but he may also make some motion that will betray his own position to the enemy. Suppose, on the other hand, that this soldier has a semi-automatic or self-loading shoulder rifle. If he locates an object he will look across the sights and take careful aim and then pull the trigger. Instantly his rifle reloads itself while he is still looking over the sights at the object he is shooting at. If the first shot is a miss all he has to do is to correct his aim and press the trigger again without even taking his eye from his target. The development of such a rifle is an engineering feat of the first magnitude and one that has never yet been solved with entire success, though several very successful hunting rifles on this principle are on the market and some military rifles of this type which are practicable though not ideal have been produced. The fact that there is on the market a hunting rifle which operates on the semi-automatic principle and handles a cartridge suitable for medium ranges (though not powerful enough for long range military work) showed a way for the Infantry to make a tactical study of the self-loading rifle while the mechanical problem of its production was being attacked by the Ordnance. With this end in view, the Ordnance purchased 25 Remington self-loading rifles, and the Experimental Department altered them for military use by putting on new sights, a sling strap and swivels and a military forearm, as shown in the photo. These rifles are now being tested by the Infantry board.



Modified Bang Semi-automatic Shoulder Rifle, Built at Springfield in 1920 by Capt. James L. Hatcher

The recognition of the importance of the subject has led the Ordnance Department to bend every effort towards the production of such a weapon. One way in which accomplishment of this end is sought is by sending out circulars inviting civilian inventors to submit such rifles for test. In addition, the Ordnance Department has assigned to Springfield Armory the task of attempting to produce a rifle of this character. About a year ago an Ordnance Officer stationed here undertook this development and in the record breaking time of about five months designed and built a rifle which showed great promise and which worked well. This rifle was a modification of a foreign gun which functioned excellently but which was clumsy in appearance and difficult to manufacture. The force used to operate this gun is the blast of gas which issues from the muzzle after the bullet has left. The new rifle was a marked improvement on the old one, but both the designer and the board that tested it saw where improvements should be made. However, owing to the shortage of officer personnel it soon became apparent that it would be impossible to spare an officer to devote his entire time to concentrate on a single project of this nature, however important the project might be, and without concentration to the exclusion of all other distractions there is little probability that success can be attained on an engineering feat involving so many ramifications and alternatives and requiring so much research as this one. Accordingly, the problem was attacked in still another manner. A civilian inventor of excellent engineering qualifications submitted to the Ordnance Department a rifle which embodied many elements of success. This gun employed a novel means of operating the mechanism, which was accomplished by utilizing the force generated by allowing the primer to move back slightly when the cartridge is fired. The gun originally submitted operated well and showed great promise, though it was evident that some mechanical improvements could be made. In view of the importance of this subject, the Ordnance Department felt that no course of action which provided a reasonable hope of success should be neglected, and accordingly obtained the services of this inventor at Springfield Armory, where he has been employed for over a year in producing the new model semi-automatic rifle which is shown in the photograph. This rifle is symmetrical in outline, convenient in form and is of almost unparalleled simplicity of design. The rifle is now nearing completion and as it has not yet been fired the results of its trials will be of the greatest interest.

Requirements of Semi-Automatic Shoulder Rifle

The rifle must be of a self-loading type, adapted to function with cartridges not less than .25 caliber or greater than .30 caliber, of good military characteristics, and preferably to fire the U. S. cartridge, caliber .30, model 1906. It must be simple and rugged in construction and easy of manufacture. It should require but little more attention than the regular service rifle when placed in the hands of the average soldier.

The following features are considered necessary:

(a) The rifle must be simple, strong and compact. Weights should be well balanced and so placed that the essential strength is given to components requiring it. Ease of manufacture should be a guiding factor in preparing a design.

(b) The mechanism must be well protected from the entrance of sand, rain, or dirt, and should not be liable to derangements due to accidents, long wear and tear, exposure to dampness, sand, etc.

(c) Components of the mechanism should be the fewest possible, consistent with ease of manufacture and the proper functioning of the weapon. Parts requiring constant cleaning or which may require replacement should be designed with a view to ease of dismounting by the use of not more than one small tool, preferably the service cartridge.

(d) The rifle must be so designed that the magazine while in position in the rifle may be fed from clips. The magazine may be detachable, but this is not considered desirable. The breech mechanism must be so designed as to preclude the possibility of injury to the firer due to premature unlocking. It is preferable that the bolt or block be positively locked to the barrel at the moment of firing. The capacity of the magazine should not exceed ten rounds.

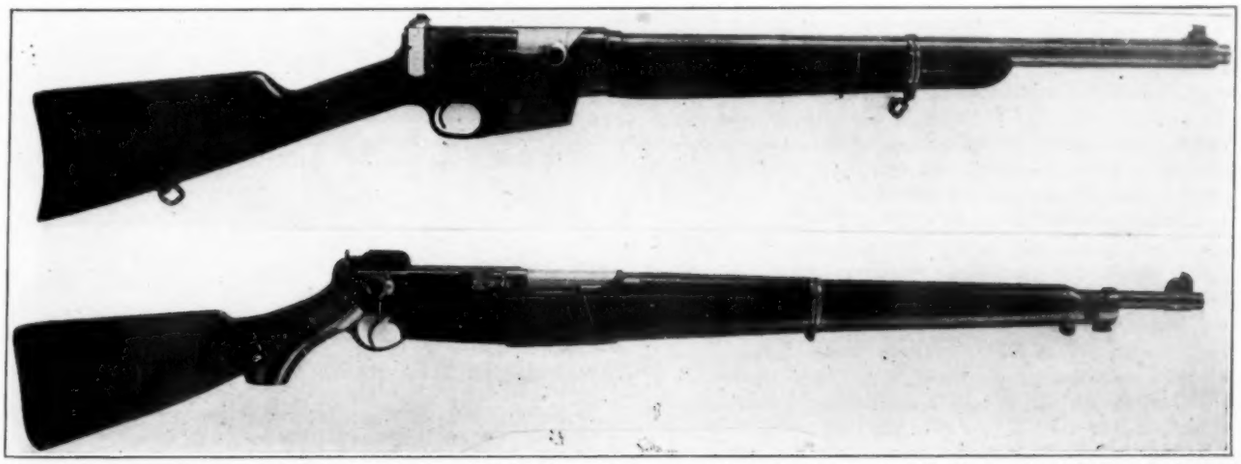
(e) The firing mechanism should be so designed that the firing pin is controlled by the trigger and sear direct; that is, the bolt mechanism should move forward to the locking or firing position with the firing pin under the control of the trigger and sear mechanism, so that the cartridge is not ignited until the trigger is pulled to release the firing pin. The bolt, or block, should remain open when the last cartridge in the magazine has been fired. In case a detachable magazine is used the insertion of a new magazine should not release the bolt.

(f) The trigger pull, measured at the middle point of the bow of the trigger, should be not less than 3 or more than 5 pounds. The trigger action should be similar to that of the present service rifle, *i. e.*, it should have a light first pull, after which there should be no appreciable backward motion until the sear is released.

(g) An efficient safety or locking device must be provided, permitting the rifle to be carried cocked and with cartridge in chamber without danger. The rifle should remain cocked and ready for firing when the safety device is unlocked.

(h) The weight of the rifle, with magazine empty and without bayonet, should be a minimum consistent with proper functioning, and in no case should exceed 10 pounds.

(i) The rifle must be so designed as to give good balance and be adapted to shoulder firing The general appearance and outline of the gun should be, as nearly as practicable, the same as the United States rifle, model 1903.



Above: Remington Semi-automatic Sporting Rifle Converted for Military Purposes. Below: Semi-automatic Rifle Designed and Built at Springfield Armory in 1921 by Mr. John C. Garand

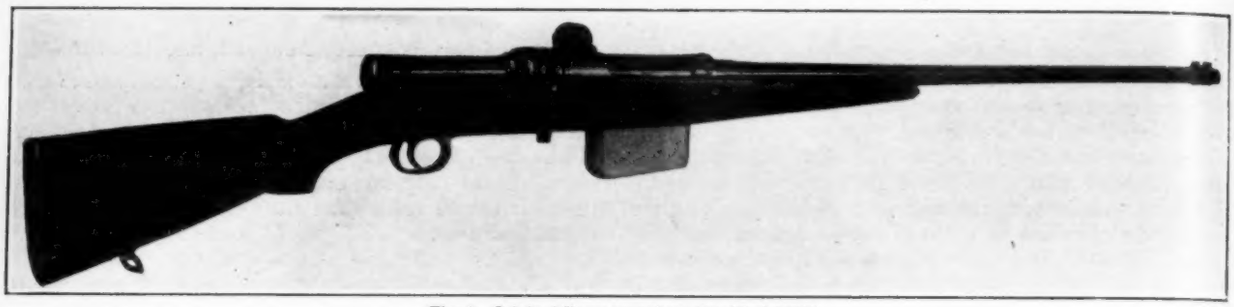


Fig. 1—Original Thompson Autorifle, Model 1919

The Thompson Autorifle

Caliber .30

By

H. E. HARTNEY

Member A. O. A.

THE development of a semi-automatic, self-loading military rifle, weighing less than ten pounds, capable of firing high-powered cartridges, has been the long perplexing problem of gun designers throughout the world. The primary problem has been the reduction in the weight of the rifle to within ten pounds, at the same time providing a sturdy automatic mechanism that could withstand the fifty thousand pounds per square inch pressure of a military cartridge.

In the past, self-functioning and automatic arms have been operated in three ways: (1) the blow-back of the gas against the head of the bolt; (2) a gas-operated piston which operates the bolt in turn; and (3) by the force of recoil. The objection to these systems has been generally; (1) the blow-back does not lock at the instant of firing, and consequently cannot fire high-powered cartridges; (2) gas operated, and (3) recoil systems add weight and complications—gears, arms, piston, etc., or move the barrel or the frame for the sole purpose of unlocking the bolt which performs no useful function after unlocking is accomplished. The latter method of unlocking is also a cause of inaccuracy in some designs, as these heavy weights are moving during the flight of the bullet in the bore or the period necessary to aim.

With the advent of the Thompson Autorifle and the Thompson Submachine Gun, another system of automatic breech closure is added to the above; namely, (4) the *self-acting lock* in which the bolt is in the form of a wedge or a screw and which *in itself without other accessories* constitutes at once an automatic lock and release. This is accomplished by the principle of adhesion, about which, outside of the experiments of General John T. Thompson and his associates during the last few years, little is known. A study of this new principle shows the advantages of the *self-acting lock* by reason of its extreme simplicity and consequent saving of weight, overcoming at the same time many of the basic engineering problems involved, as the weight thus saved can be placed where most needed.

This principle was observed and patented by Commander John Blish of the U. S. Navy, and presented to a special Board of Naval Ordnance before the World War. Commander Blish's basic claim, among others, in the words of the Board, was:

"That in any breech closure consisting of a breech plug housed in a suitable housing and having two pressure resisting surfaces, the forward surface disposed normally to the axis of the bore and the rear surface inclined thereto and bearing upon a suitable surface of the housing, the force of adhesion will immovably fix or clamp the breech block under heavy pressure, but at a comparatively small pressure, whose value depends upon the inclination of the two surfaces referred to, the force of adhesion ceases to act and the breech block is rendered free to move under the influence of the forces then existing.

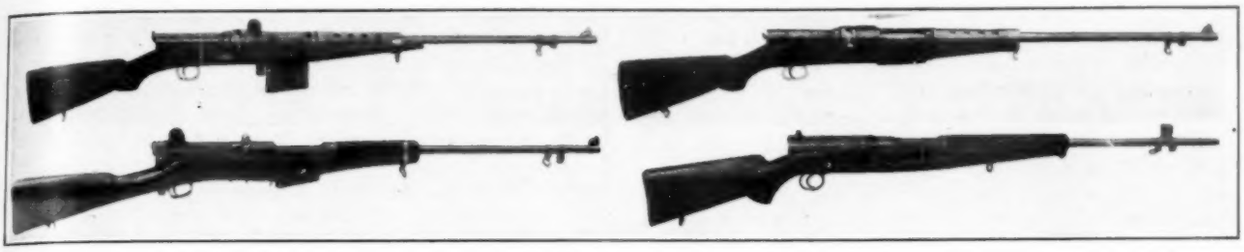
"It is readily seen that this claim is a very broad one, and brings within its scope practically every known type of breech closure, whether it be of the wedge or screw type.

"On the subject of adhesion, the Board finds the literature scant. In every-day life this force manifests itself chiefly in the adherence of liquids to solids, especially when such liquids 'wet' the solids—for example, water and glass. It may be noted, however, that the efficiency of all glues and cements depend largely upon the force of adhesion. Occasionally it manifests itself in two solids, such as when two plates of polished glass adhere with sufficient force to render it difficult to separate them without breaking them.

"Adhesion is a molecular force which binds together the surface of molecules of two bodies at the common surface of contact. Everything goes to show that intimacy of contact conduces to the existence of adhesion. If two bodies are pressed together, the pressure increases the intimacy of contact, especially if the pressure be great, and thus indirectly causes the surfaces to adhere. If the pressure be gradually reduced, the contact becomes less perfect and a point is reached where the contact is not sufficiently perfect for the surface to adhere—adhesion ceases and the surfaces are free to move under the influence of such other forces as may exist at the time.

"So long as the surfaces do adhere they are locked together by the force of adhesion, and resist any sliding upon each other much as the force of cohesion resists the sliding of the molecules of a continuous body under the influence of a shearing force.

"Two remarkable facts were made manifest by these experiments, (1) the breech opened when the wedge angle was considerably below the angle of repose, when friction might have been expected to hold the block after the adhesion ceased; (2) with the larger wedge angles considerable pressure in the bore still compressed between the cartridge case and the wedge housing with considerable force. Under such circumstances one would expect abrasion of the contact surfaces when



Thompson Autorifles

Fig. 2—Upper left: Thompson Autorifle, Model 1920. This rifle accomplished the unique record of firing for the first time the 5,000-round Springfield Endurance Test in 1920 without breakage or repair.

Fig. 3—Upper right: Colt Autorifle, Model 1921, designed by Colt's Patent Fire Arms Mfg. Company of Hartford, based on Thompson Autorifle, Model 1920.

Fig. 4—Lower left: The Thompson Combination Automatic and Semi-Automatic Machine Rifle, Model 1921, weight 11 lbs. The mechanism of this rifle is designed for quick conversion into a tripod mount with heavier barrel for the heavy machine gun type.

Fig. 5—Lower right: The Thompson Autorifle "P," Model 1921, basically designed from Model 1920. Built by the Auto-Ordnance Corporation of New York.

movement took place, but no such abrasion was discernable.

"The rifle mechanism was especially interesting for several reasons, viz, (1) the wedge angle was considerably less than the angle of friction; (2) sufficient pressure remained in the bore when the wedge opened for the empty cartridge case to be blown to the rear, carrying the bolt (containing the firing pin and firing spring) before it with sufficient velocity to cock the firing pin when the bolt brought up against the rear buffer, and causing the empty cartridge case to rebound and to be ejected to the front. This movement of the bolt to the rear was against the force of compression of a spring designed to reload the piece.

"From what has been said it is evident that in practically every breech mechanism in existence the force of adhesion must come into play, that there is no tendency for the mechanisms to open under heavy pressure, and that the so-called safety locks or latches serve only to restrain the tendency of these mechanisms to open after the adhesion has ceased.

"Commander Blish's system of breech closure lends itself naturally for use in automatic or semi-automatic small arms, machine guns, and guns using fixed ammunition."

Perhaps the clearest example of Commander Blish's principle is the case of firing reduced or saluting charges in guns of large caliber, where it has been often observed that the screw breech block at times automatically opened or tended to open; whilst firing full charges this phenomenon very seldom occurs. The principle of opening at the low and holding on the high pressures is thus shown in breech mechanisms of the screw type even in cannon. Bearing in mind that the screw is the mechanical equivalent of the wedge, Commander Blish's embryonic mechanisms allowed the variation of the angle of inclination of the surfaces of a wedge and he deduced that the smaller the inclination, the smaller the pressure at which the adhesion ceases, but he did not attempt to formulate the relation existing between these quantities. He also discovered that the cessation of adhesion under diminishing pressures apparently was very abrupt and it was logical to infer that under increasing pressure the force of adhesion is called into existence in an equally abrupt manner.

The first piece of mechanism that successfully demonstrated the Blish principle was the Thompson Submachine Gun, now generally known and on the market, which was described in the issue of ARMY ORDNANCE for November-December, 1920. In this form the simple wedge was successfully used as a self-acting lock. The next development of the principle has been the Thompson Autorifle, in which the screw form of bolt was utilized as the self-acting lock. The Autorifle has been basically considered as an engine—in fact as a double acting gas engine in which the bullet and the bolt have motions of translation in opposite directions and are moving pistons. Considering the importance of proper lubrication in automobiles or other gas engines, the lubrication of the automatic gun or powder engine with its correspondingly high pressure and frictional resistance has been considered even more essential. This results in the automatic oiling feature of the Autorifle wherein the added complication and weight to the simple light breech mechanism could be incorporated without exceeding the limit of ten pounds. Basically, proper automatic oiling of any mechanism was considered as naturally prolonging the life of the machine.

Those experienced in the actual use of automatic guns are almost unanimously agreed that the oiling of cartridge cases insures more certainty of action. In fact cartridge case oiling was prevalent in the field during the World War. This practice was accomplished crudely with an oil can before loading. The reason for this is obvious when it is realized that extraction, which is the heart of the automatic problem requires varying forces. The extraction pull necessary for cartridges has a wide variance due to the adhesion of the case to the chamber and also due to the fact that in some gas and recoil automatic guns the instant of applying or timing the pull is not always the same for each shot, especially where the rate of fire can be regulated in such guns. Experiments show conclusively that oiling decreases the variation in the force required for extraction and consequently makes it more uniform. With the more cumbersome unlocking apparatus of some gas and recoil systems, an accurate timing of the extraction is almost impossible. This results generally in uncertainty of action. After exhaustive tests the *timing* of *extraction* has been covered in the Autorifle by its special design and construction.

The Autorifle is loaded in exactly the same manner as the Service Rifle. In doing so, however, the cartridge cases are automatically oiled. This changes the back pressure on the bolt from that known to be exerted by dry cartridges. Hence, after exhaustive tests, its use in the Service Rifle has been discouraged by certain experts. However, in guns specially designed and with mechanisms *timed* particularly for such pressures as in the Thompson mechanisms, this point is safely taken care of and large factors of safety are secured. As the bullet is neither oiled nor greased, the ballistic qualities of the bullet remain unaltered. The mechanism, however, gives a considerable reduction in recoil with corresponding advantages in accuracy of firing.

In appearance and general form, the *Thompson Autorifle* is a replica as far as possible of the present U. S. Service Rifle. In fact, out of a total of 95 component parts for the U. S. Model 1903, thirty of the total 86 parts of the Autorifle are the same as in the Service piece. The design allows the Autorifle to be completely dismantled and assembled rapidly. Dismantling for replacement of moving parts is accomplished without the use of tools and is simple. Comparing the gun mechanism proper consist-

ing of all parts necessary for free functioning the Autorifle has 44 parts contrasted to 42 for the U. S. Model 1903. The total weight of the Autorifle is 9 pounds and 10 ounces.

Magazines are either detachable holding 10 or 20 shots or fixed as desired, the latter holding the regulation five cartridges. The Autorifle can be conveniently used as a hand loaded weapon when desired, reserving the semi-automatic feature for emergencies. The mechanism functions equally well with powder charges 40 per cent below or above normal pressures of 50,000 pounds without adjustment of any kind.

Turning from the mechanical aspects of the military semi-automatic problem to the tactical considerations of the case, the advantages of semi-automatic fire in battle are not fully conceded by all military experts. Rapidity of fire, however, has been one of the most important considerations affecting the design of Small Arms since time immemorial. The invention of the breech loading principle by Hall in 1664, the percussion principle attributed to the Englishman Forsyth, along with the pin fire cartridge by the Frenchman Houiller in 1847, and the adoption of magazine Small Arms by the German Army in 1865, all paved the way of improvement by increasing the possibility of rapidity of fire.

Since the battle of Lexington, probably no tradition of our army is cherished so dearly as the proverbial marksmanship of the American soldier. This tradition has been fostered by the most careful training methods to such an extent that it is seldom, if ever, an American Rifle Team is defeated in international competition. The degree of proficiency obtained by American Army training methods with the enlarged forces involved in the war, was certainly successful in that the American soldier, as a rule, was superior in marksmanship to his allied comrades in arms, and equal to at least the best trained enemy forces. With the advances made during the last century in the application of the principle of replacing man power by machine power, the advent of automatic fire in replacing hand-loaded fire cannot be far distant, just as the fast moving taxicab replaced the slow moving horse vehicle. If, in order to hold a position that is opposed by isolated units of automatic fire, it is necessary to thickly concentrate marksmen using hand-loaded weapons for the purpose of maintaining fire superiority, many believe our World War experience has shown us that the price is paid in blood.

At the critical moment that occurs in every battle, other things being equal the side which brings the preponderance of lead to bear will be victorious. If, by the adoption of a semi-automatic shoulder rifle it is made possible for the soldier to deliver at a critical moment forty aimed shots per minute against the soldier who with his hand-loaded weapon fires twenty, the result can be surmised.

However, in the past, the semi-automatic shoulder rifle weighing under ten pounds in weight and firing the high-powered military cartridge has not only proven unreliable in its certainty of action, but totally unable to endure the many rigors required of it. If the *Self-Acting Lock* is an answer to the many problems involved, the prestige of the American Gun Engineer will move one step higher where in the past it has been raised pre-eminent throughout each decade by such names as Hall, Maynard, Henry, Sharp, Rider, Lewis and Browning.

[NOTE.—Colonel Hartney, author of the above article, has recently resigned from the Army Air Service to accept the position of Managing Director, Aero Club of America. During the World War he was Commander of the First Pursuit Group, American Expeditionary Forces. For his gallant and effective work with this organization he was awarded the Distinguished Service Cross, the Croix de Guerre, the Italian Silver Medal for Valor, and was made a member of the Legion d'Honneur.—ED.]

The New Larsen All-Metal Attack Plane

Under the above title, the *American Army and Navy Journal*, on November 5, 1921, printed an article by the author of our preceding article, which read in part as follows:

Eminent naval strategists and tacticians admitted last summer after the bombing tests were over that they would be forced to give the airplane more consideration hereafter in all naval and war preparation. Already another phase of aviation warfare is before the public and may give the Army tactician just as rude a shock as it did the Navy, for it threatens to upset calculations and war plans on land radically. Attack aviation is that portion of military air forces that aims at ground troops and ground harassment generally. It developed during the last few months of the war, but owing to the limitations of production was used very little on either side. Ludendorff was one of its strongest advocates, but its possibilities were appreciated and an approximation thereto was attempted by our own American troops, particularly those of the first Pursuit Group. Those fliers who from low altitude bring fire power to play on enemy forces either coincident with or irrespective of the infantry waves of attack, who act more or less independently of the ground troops for purposes purely offensive were classified during the last few days of the war as attack aviators and their work was deadly.

To be successful an attack plane must be armored, it must have great speed, it must be able to operate from a base far in the rear, it must have a good climb, but, above all, it should have overwhelming power of fire. To deprive it of its armor would be certain destruction, for it must fly at extremely low altitude, not more than 400 feet; to rob it of speed or range of action would be a handicap and to take away its fire effectiveness by having only a few machine guns aboard would be to deprive it of its very function—fire power delivery. Pursuit planes of the World War would not suffice, much less would the makeshifts built up around old DH4s or Martin bombers. Something entirely new had to be brought out, and it appears that a private citizen, Mr. John M. Larsen, will be credited with the solution of a problem that for some time to the airman has seemed without solution. Certainly his product demonstrates beyond question that he is an aeronautical engineer with a keen insight into aerial tactics, for the whole layout seems calculated to fall in line with the acknowledged requirements of such a plane.

For the benefit of those readers who have not been fortunate enough to inspect this new machine it will suffice to state that this plane is all-metal in construction, is equipped with a Liberty 400-horsepower motor, has great range of action, speed and climb far beyond that of any machine its size existing on the front during the war, and the startling thing about it is that it has thirty Thompson Submachine Guns aboard and one man can operate them and control their fire with perfect ease.

Each Thompson Submachine Gun fires at the rate of 1,500 shots a minute or a fire rate of 45,000 shots a minute for the plane. These figures have never heretofore even been approached.

Self-Propelled Track-Laying Artillery*

By

WILLIAM T. CARPENTER

Member A. O. A.

PART II. THE SELF-PROPELLED TRACK-LAYING GUN MOUNT

THE idea of the self-propelled gun mount is an old one and followed closely the introduction of gun powder and the cannon into warfare, efforts having been made in the early days of the cannon to propel it on wheels by men and animals riding in the vehicle itself. Muscular power of course proved insufficient. Battle cars carrying both cannon and riflemen and moved by men and animals harnessed within were tried out in the 14th and 15th Centuries. The development of the mechanically self-propelled gun vehicle has taken place only in recent years and apparently owes its final development to the gas motor. This is particularly true of the strictly field artillery types, both light and heavy. This development has taken place in the following order:

Armored car,
Anti-aircraft gun,
Tank,
Self-propelled "Caterpillar" or track-laying gun mount.

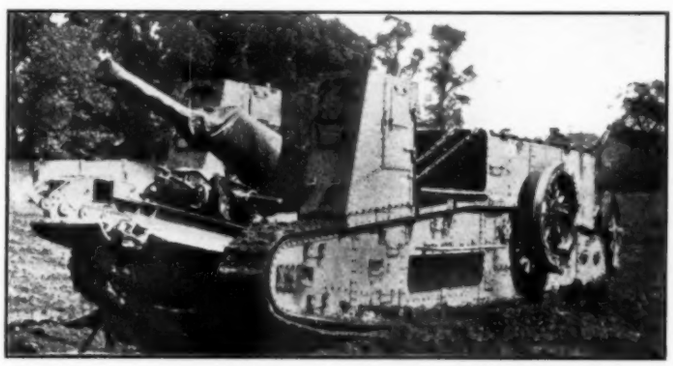


Fig. 13. British Gun Carrier Tank

I have been unable to find any references which would show or indicate any actual attempt to apply the steam engine directly to the cannon as a self-mover, and it is quite probable since the steam tractor came into being after the war of 1870, and in turn was practically supplanted by the gas engine tractor before the late war, that no serious attempts have been made to use steam for this purpose, unless it was in connection with the early type of the armored car and perhaps later on with some types of anti-aircraft artillery. Only the lightest of cannon have been used on armored cars, which have all been of the wheel types, and the majority of self-propelled anti-aircraft gun vehicles have been of such light structure that it has been necessary to support or raise the gun platform and thus take the load of the gun off of the wheels when firing. Both the armored car and anti-aircraft artillery vehicles were in use by the leading Powers before 1914.

In the early days of the late war, the engineers of the Holt Manufacturing Company suggested the "Caterpillar" Tractor as a suitable vehicle for carrying a gun. They presented the idea to the various Allied Missions engaged in the procurement of munitions in this country and also to our Ordnance Department, which in 1916 authorized the Holt Company to design and construct a self-propelled "Caterpillar" carriage for the 3-inch Anti-Aircraft Gun. This, it is thought, was the first self-propelled gun mount of the track-laying type to be constructed in this or any other country. This experimental gun mount was completed and satisfactorily tested early in 1917, and in June of the following year, an 8-inch Howitzer, British, Mark VI, mounted on a crude wooden-top carriage was fired from this same vehicle at the Aberdeen Proving Ground with such success as to demonstrate thoroughly the practicability of this type of carriage for heavy guns. It was about this time that "Caterpillar" treads were applied to the wheel carriages of both the 8-inch Howitzer and the 155-mm. G. P. F. Gun in place of their wheels, giving most satisfactory results in both firing and maneuvering tests as compared to their performances on wheels.

So far as I have been able to learn, France was the only other power which really attempted to develop self-propelled artillery of the track-laying type during the war and no information is available covering any experimental work along this line since the war by countries other than the United States.

Great Britain's great mechanical achievement of the war was the Tank, the development of which was started in the fall of 1914. The idea of the tank met with considerable opposition and the struggle of its development overshadowed all other ideas of a kindred nature and though the basic idea of a self-propelled artillery carriage was suggested in this and other forms, very little was attempted towards the development of such a mount solely for field guns. The idea, however, nearly reached a practical state of development in the production of a modified tank called the "Gun Carrier Tank," a tank which was provided with an elongated tail forming a platform for mounting the wheeled carriage of either the 60-pounder .Gun or the 6-inch Howitzer, either of which could be transported or fired on this vehicle. When so mounted, the wheels of the gun carriage were removed from the same and placed in hangers on the sides of the tank body and the remainder of the gun carriage was then secured to the tank platform. Special arrangements were provided for sliding the gun carriage off the platform and replacing the wheels so that the gun could be fired from the ground if desired. Space

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was provided for carrying 60 rounds of 60-pounder or 64 rounds of 6-inch howitzer ammunition. The chain-treads were driven by a 6-cylinder, 105 B. H. P. Daimler gas engine and a maximum speed of 4 M. P. H. was attained. This tank was 30 feet long without the tail wheels with which it was originally equipped, and 11 feet wide overall. It weighed 25 tons without gun and ammunition and 34 tons with either gun or ammunition supply.

It is understood that a number of these "Gun Carrier Tanks" were built and that some were tried out in action on the Somme in August, 1917, with satisfactory results, but either through lack of interest or else through necessity, these tanks were used chiefly for carrying supplies across country in 1918. With the guns removed they had a cargo capacity of 10 tons.

French Self-Propelled Artillery

Up to the end of the war this type of artillery had not reached the production stage in France, though orders had been placed by the French Government for a number of self-propelled chain-tread gun mounts of the Schneider type and for a considerable number of units of the 2-piece chain-tread artillery material of the St. Chamond type, both of which are described later.

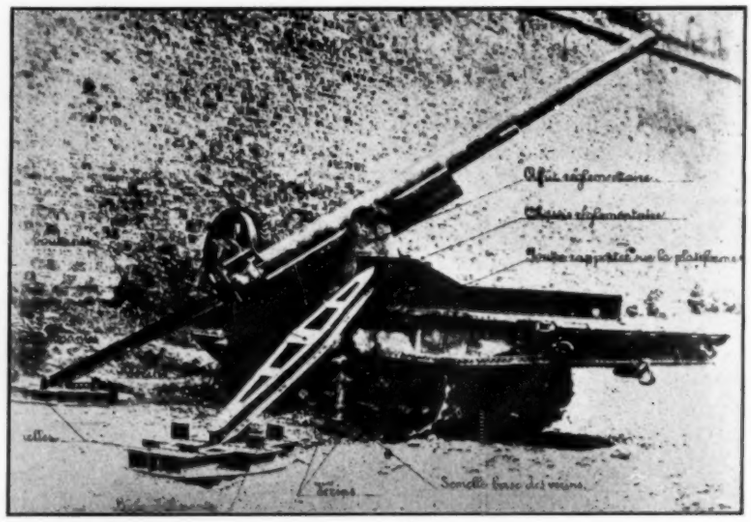


Fig. 14. Renault Experimental Mount for 155 G. P. F.

In 1917, the St. Chamond Company produced at their works in France an experimental self-propelled gun mount of the track-laying type, which seems to have been the initial effort along this line in that country, and on which they mounted the 120-mm. St. Chamond Gun. The gun and cradle weighed 4,400 pounds, and the combined weight of the gun and mount was 45,540 pounds. The chain-treads were motor driven, the motors receiving their power from a gas-electric set installed on the chassis.

The top carriage for the gun was rigidly connected to the vehicle platform through which an opening was provided for the recoil of the gun when fired at high angles. Though the vehicle was entirely too heavy for the size of the gun, which was of a caliber later on rejected by the French Government for its use in any form, the gun mount created a considerable amount of interest and the tests, which were very satisfactory, showed that a gun of much higher power could be fired from this type of carriage. In appearance, this vehicle resembled very closely the chain-tread gun mount later produced by this company for heavier guns.

In 1918, experiments were conducted with a 75-mm. gun on a Renault Tractor mount. The gun was mounted on a Renault Tank from which the turret had been removed and tests were made with the gun located over the idlers as well as over the driving sprockets. No information is available as to the results of these tests or as to the conclusions derived from them with reference to the use of the 75-mm. gun on this type of carriage.

Early in 1918, the Schneider Company designed a self-propelled chain-tread mount for the 220-mm. long gun which was very similar to the Mark III mount produced by our Ordnance Department for the 240-mm. Howitzer. The development of this materiel was guarded very carefully and though orders were placed by the French War Ministry for several of these mounts, it is understood that the pilot mount was not completed or tested until after the Armistice. This mount is particularly interesting from the fact that it was provided with two gas motors mounted on its chassis, a main motor of 100 H. P. and an auxiliary motor of 16 H. P., the purpose of which was to propel the vehicle in case of accident to the former, though of course at a very slow speed, and also for traversing the vehicle. The reduction system employed in the traversing train permitted of traversing by means of the auxiliary motor at an angular speed of about 14 mils per second with the motor turning at 1,000 R. P. M. A hand wheel was also provided for traversing in emergencies, in which case it was to be applied to the auxiliary motor in place of the starting crank.

The chain-tread system was of the rigid bearing type. The frame was of the open box type with an opening in the center for the recoil of the gun which was mounted on a top carriage, which recoiled up two inclined rails with a hydraulic brake between the top carriage and the frame. Stability in firing was accomplished by braking the tracks.

The power of the main engine was transmitted through a disc clutch to a 4-speed gear transmission, which gave the same speeds forward and reverse. The maximum speed of the vehicle was to be about 4 miles per hour. This carriage was 2.65 meters in width, 11 meters overall in length and the total weight was about 35 short tons. A frame for supporting the motor extended to the rear of the gun platform and formed a considerable overhang which would undoubtedly have proven objectionable in the field.

Late in 1918, an experimental mount for the 155-mm. G. P. F. Gun was developed and one was built, by using a modified 10-ton Renault Tractor with gear driven chain treads and a 110 H. P. airplane motor located in a housing on top of the platform. The mount was arranged to receive the top carriage, chassis, elevating and traversing mechanism of the wheel mount. In order to fire the gun it was shifted from its traveling position in the center of the platform to the left-hand side of the same and pointed crosswise. Two large outriggers with spades were attached to the platform to stabilize the carriage and jacks were also provided to support the platform. This arrangement gave a field of fire of 60 degrees. The total weight of gun and mount was about 19 tons. This mount was considered as a makeshift and the tests indicated the necessity for many changes in its design, the most important of which were a longitudinal firing position with an opening in the platform for the recoil of the gun, provision for a 10-de-

gree traverse of the gun and the location of the outriggers at the rear of the chassis. It was thought that with the modifications proposed the mount would be fairly satisfactory and the proposed changes were in progress at the end of the war.

Following their experiments with the 120-mm. self-propelled chain-tread gun mount, the St. Chamond Company produced a radically different type of chain-tread artillery materiel, an experimental self-propelled gun unit in two pieces for their 220-mm. Howitzer, Model 1917. This materiel consisted of two chain-tread vehicles of similar size and chassis construction, one of which was a gun mount and the other a limber which was self-propelled and served as power plant for both, and as a vehicle for ammunition, equipment and gun crew. The tracks of both vehicles were driven by electric motors through a system of spur gears between each motor and its track, the electric current being supplied by a generator directly connected to a 4-cylinder gas engine of 120 horsepower mounted on the chassis of the limber. The generator was compound wound, 4 poles with interpoles, with a continuous rating of 400 volts, 200 amperes at 1,200 R. P. M. The traction motors were series wound, with two windings, one in series with the armature and the other in series with the line, 4 poles with interpoles, with an intermittent rating of 200 volts, 260 amperes at 425 R. P. M. Both vehicles could be turned by means of handwheels connected with the treads.

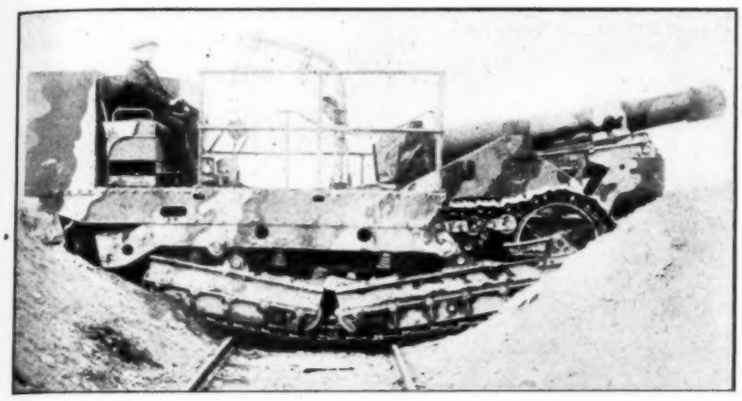


Fig. 15. S. P. Caterpillar Mount, Mark I, for the 8-inch Howitzer Mark VIII½ (British)

The gun mount was equipped with wheels in addition to the chain treads. The wheels, a detachable one on each side and one in front for steering, were not motor driven and were intended for use in towing the gun mount on good roads. When the wheels were in place, the chain treads cleared the ground by several inches. The operations of attaching or removing the wheels each required about one hour and the services of 12 men.

The howitzer was mounted on a top carriage which recoiled up two rails inclined at an angle of 6 degrees with the gun platform, the amount of recoil being controlled by hydraulic brakes. The gun returned to battery by gravity.

The unit could be operated under its own power as follows:

The limber running alone.

Vehicles coupled mechanically only and limber acting as tractor.

Vehicles coupled mechanically and electrically and gun carriage acting as tractor. (In emergencies only.)

Vehicles coupled mechanically and electrically and both motor driven.

Vehicles coupled electrically only—both en route.

Vehicles coupled electrically with limber as stationary power plant.

The normal running arrangement was with gun carriage in rear and coupled both mechanically and electrically to the limber, the motors running in parallel. The driver of the limber controlled the speed and direction of the unit and the driver of the gun mount kept his vehicle in line by means of the steering controller and foot brakes. Steering and reversing controllers and foot brakes were provided for each vehicle. Though either vehicle could act as tractor and tow the other, towing could not be employed to advantage in either case except on level and fairly smooth ground.

The drivers' platforms on both vehicles extended far out to the front, forming a serious overhang which characterized the appearance of these two vehicles.

The road tests of this materiel were concluded in January, 1918, and were most satisfactory to the French Commission in charge, which recommended its adoption as a type for heavy artillery with certain modifications in design, among which were the following:

Elimination of the wheels of the gun carriage, since it was found that little if any advantage was gained by their use in towing on roads.

Modification of the gun carriage so as readily to mount heavy guns of different calibers.

Reduction of the excessive nose or overhang of both vehicles to facilitate movements over rough ground where shell holes and trenches would be encountered.

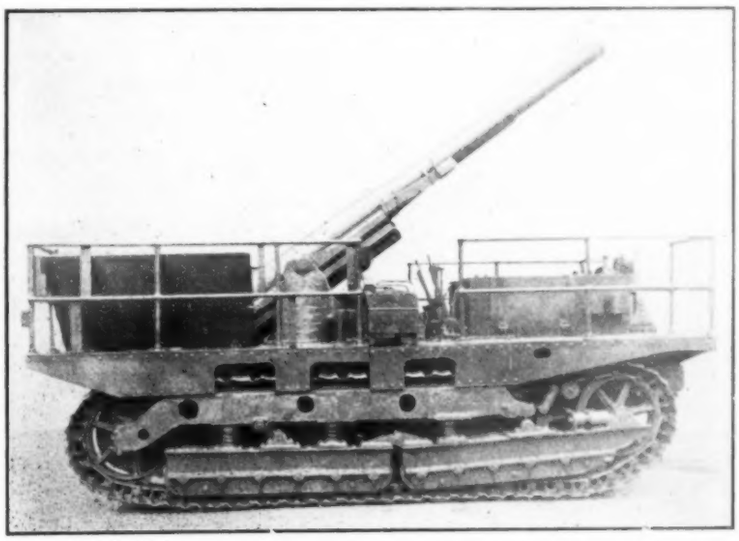


Fig. 16. S. P. Caterpillar Mount, Mark II, for the 155-mm. Gun, Model 1918 (Filloux)

Increase width of track shoes by 5 centimeters to reduce unit ground pressure.

A unit which embodied the desired modifications was produced at once and exhaustive tests were made with it at the front in the summer of 1918, including firing at enemy targets. These tests were made with the 220-mm. St. Chamond Howitzer, Model 1917, and it was found that the car-

riage possessed great stability, particularly so when fired with the rear jacks in place. The displacement in direction varied from 0 to 15 mils, depending upon the nature and condition of the position. The jacks, four for each vehicle, were intended primarily for use in repairing the tracks and also for levelling the gun mount when necessary in laying the gun.

Traversing was accomplished by moving the gun carriage either by power or by hand wheels, and by use of its motors the carriage could be turned through 360 degrees in from 15 to 40 seconds. Traversing by hand was necessary in the final setting of the gun, and a speed of about 1 mil per second was easily obtained by this method.

The total weight of the gun carriage with equipment was about 51,700 pounds, while that of the limber with munitions, equipment and gun crew was 61,600 pounds.

As a result of the final tests the French Government ordered a considerable number of units of this materiel for mounting various heavy calibers which included the 220-mm. Howitzer, St. Chamond, the 280-mm. Howitzer, Schneider, and the 155 and 194-mm. Filloux Guns.

This materiel was the same in appearance as the U. S. Mark IV-IV A, shown in Fig. 18, which was built in this country from plans furnished by the St. Chamond Company.

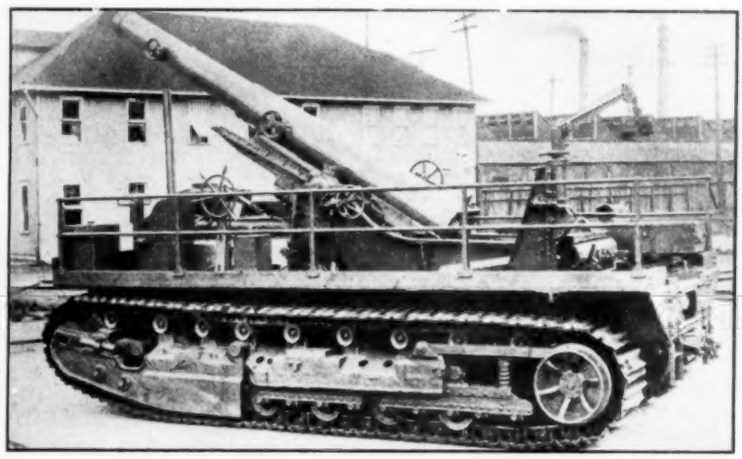


Fig. 17. S. P. Caterpillar Mount, Mark III and IIIMI, for the 240-mm. Howitzer, Model 1918 (Schneider)

Advantages and Disadvantages of the St. Chamond Type

The gun mount of this type is not, strictly speaking, a self-propelled carriage, though with the limber, the dual unit is of the self-propelled type and should be considered in connection with the subject. The materiel as a type has little, if any, economical or tactical value over the combination of simple gun mount on chain treads with a tractor of the chain-tread type affording the same rate of speed. The use of the limber as an ammunition carrier lessens the mobility of the unit of which the gun is the vital element and any advantage that may be claimed for a gas-electric motor driving system is obtained at the expense of a constant power loss of from 20 to 30 per cent.

A gas-electric gun mount or any other field weapon with no means of propulsion other than electricity is fundamentally dangerous and lacks the reliability so essential for use in field warfare. The application and use of electricity has, it is true, attained a most practical stage in our mechanical development of to-day, but there still remains the inherent danger of grounds and short circuits with resultant "burnouts" due to moisture, dust and mechanical injuries. The time is not quite ripe for this use of electricity, and the writer ventures the assertion that for the present at least, the less electricity we use in weapons of war the more reliable they will be and the electric motor in its present state should not be depended upon for propelling such vital weapons of land warfare unless paralleled by alternate mechanical means of adequate power.

The advantages of this type though greatly outweighed by the disadvantages may be summarized as follows:

Simplicity of the gun mount.
Less unit weight per vehicle, each within capacity limit of French Railway cars.
Flexibility of power application and control.
No gears to shift in maneuvering.
Availability of limber for tractor purposes in stabilized warfare.
Ammunition supply always with the gun.

The disadvantages of the type as compared to the self-propelled gas motor type appear to be as follows:

Gun mount not self-propelled.
Unit occupies greater road and cargo space.
Greater total weight—a serious detriment in both maneuvering and shipping.
More expensive and difficult to manufacture and maintain.
Hard to control, as the speed of the gun carriage is entirely in the hands of the driver of the limber, requiring team work between the drivers of the two vehicles.
Difficult to steer, particularly the gun mount when coupled both electrically and mechanically to the limber, due to change of speed of motors as tracks encounter uneven ground surfaces.
Serious power loss of gas-electric drive with corresponding mobility loss for the unit.
Vulnerability and resultant unreliability of electrical drive.
Requires highly trained electricians to operate and maintain the unit.
More difficult to conceal.
More difficult to get gun to position.
Requires more personnel.

American Self-propelled "Caterpillar" Artillery

Upon our entry into the late war the country at large was confronted with the immense munitions problem of furnishing vast quantities of war materials of all kinds for ourselves and our allies. Lack of interest in preparedness by the American people as a nation had caused us to be practically without munitions or the ways to provide them for a land war of this magnitude. Our small Ordnance Department had to meet the thousand and one demands for weapons and fighting material for an army numbering millions. To meet this situation it was first necessary to begin at the bottom and build up a vast organization to direct the activities of the nation in its eagerness to provide everything wanted.

Among those demands of great importance to our own artillery program was the design and production of "Caterpillar" Tractors of various sizes, the necessity for which was most apparent. In a relatively short time this problem reached a happy solution in the immense production program previously mentioned. The Department was then in position to take up the production of the "Caterpillar" gun mount to meet the conditions on the Western Front which demanded greater mobility for heavy artillery. As a result of the early experiments in this country and those in France the possibilities of the self-propelled gun mount of this type were by this time fully appreciated by the artillery

and ordnance experts of both countries, who were convinced that an extensive production program of this type was fully warranted.

In this connection it should be borne in mind that with the intense struggle on all sides for the production of ships and munitions of innumerable types then in use, the introduction of a distinctly new type of weapon such as this was a most serious matter, since it materially increased the demands upon the munitions industries which were already fully occupied.

About June 1, 1918, the design of self-propelled "Caterpillar" artillery was undertaken by the Engineereing Division of the Ordnance Department with Mr. P. E. Holt directly in charge. Mr. Holt was the designer of the self-propelled "Caterpillar" mount for the 3-inch Anti-aircraft gun previously mentioned. The policy of the Ordnance Department in undertaking this work was first to develop the most promising types suggested by the results previously obtained in this country and France and after suitable tests with experimental units, or pilot mounts as they were called, to select those types best suited to the different gun calibers demanded by the conditions at the front and to put them in production. In furtherance of this policy the following types were studied and developed to a more or less extent by the staff of designers:

S. P. "Caterpillar," Mark I, for the 8-inch Howitzer, Mark VIII½.
S. P. "Caterpillar," Mark II, for the 155-mm. Gun, Model 1918 MI (Filloux).
S. P. "Caterpillar," Mark III, for the 240-mm. Howitzer, Model 1918 (Schneider), (main frame and top carriage of cast steel).
S. P. "Caterpillar," Mark III, MI, for the 240-mm. Howitzer, Model 1918 (Schneider), (main frame and top carriage of structural steel).
S. P. "Caterpillar," Mark IV (St. Chamond type), for the 240-mm. Howitzer, Model 1918 (Schneider), (electric motor driven tracks).
S. P. "Caterpillar," Mark IVA (St. Chamond type), Gas-electric power unit.
S. P. "Caterpillar," Mark V (St. Chamond type), for the 240-mm. Howitzer, Model 1918 (Schneider), (electric motor driven tracks).
S. P. "Caterpillar," Mark VA (St. Chamond type), gas-electric power unit.
S. P. "Caterpillar," Mark VI, for the 3.3-inch Gun.

In all this work special effort was made to utilize commercial standard power units, parts and "Caterpillar" Tractor parts available at the time in this country, in order to expedite development and production and thus lessen the resultant demands upon the munition industries. Due to the fact that this type of materiel had not been subjected to the actual test of prolonged service in action at the front, it was considered advisable to use a liberal factor of safety in the design of those essential structural and driving parts upon which the greatest stress would fall, in order to play safe in the production of these carriages so that there would be no doubt as to their ability to withstand the severe demands of prolonged service in the field. In this way production could be greatly expedited after the experimental tests with the pilot mounts and the selection from them of the most favorable types. It was due to this that the types produced appear now excessively heavy in comparison with present limiting weights.

In addition to the "Caterpillar" gun mount program it was also necessary to develop similar types of "Caterpillar" Tractor cargo vehicles for hauling artillery ammunition and supplies and two types were designed and put in production. They were designated at the time as the Mark VII, 3-ton Platform Tractor and the Mark VIII, 5 or 6-ton Platform Tractor.

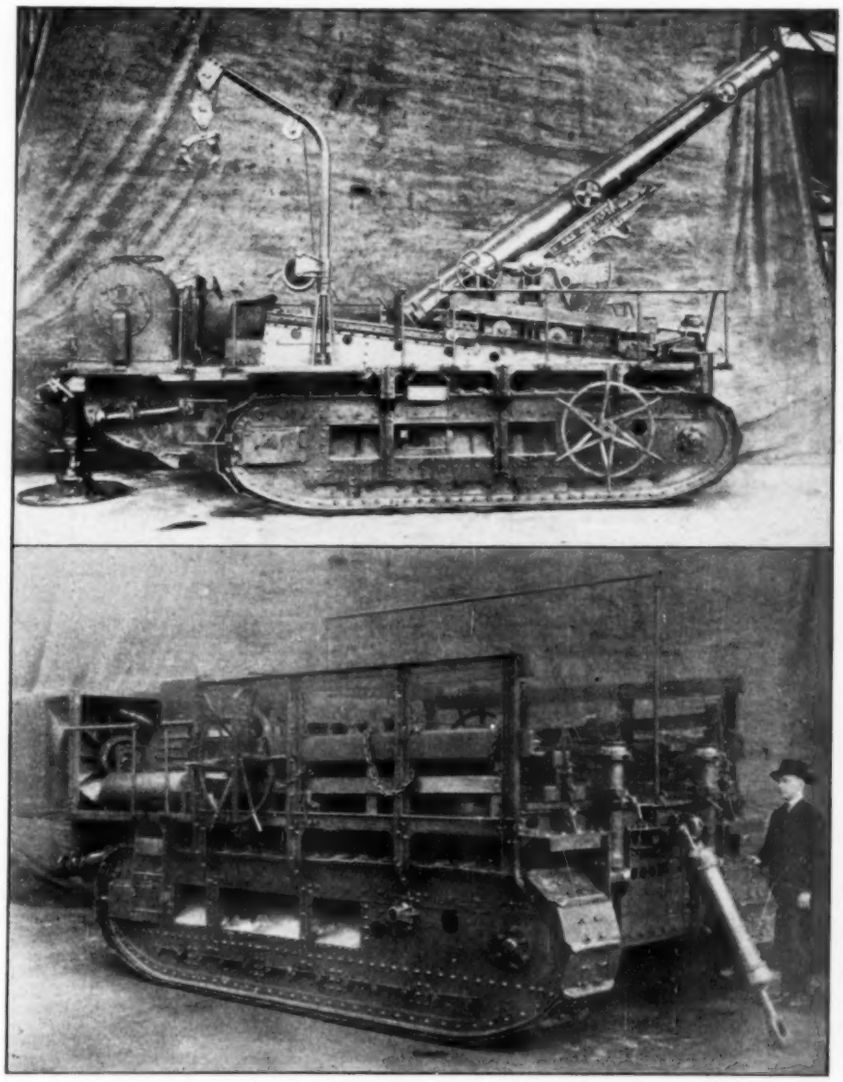


Fig. 18. S. P. Caterpillar Materiel, Mark IV-IVA, for the 240-mm. Howitzer, Model 1918 (Schneider)

Of the gun carriage designs listed above, the mounts known as the Mark I, Mark II, Mark III and III MI, and Mark IV-IV A, were in quantity production at the end of the war. After the Armistice the production program was cancelled except for the pilot mounts and eight production mounts of the Mark II, and a few of the Mark VII cargo vehicles.

In each type developed a traverse of 360 degrees is readily obtained by maneuvering the tracks. Since the various types of "Caterpillar" artillery produced in this

country to date have been fully described in Ordnance Department publications and various magazine articles, no extended description of each will here be attempted.

The Mark I, for 8-inch Howitzer, Mark VIII ½

This mount is in general similar to the experimental mount completed and tested in 1917, and the entire top carriage of the standard Mark VI and Mark VII 8-inch Howitzer carriage was mounted on the main frame of the vehicle in a manner which gives the same gun elevation and traverse of the top carriage as permitted by the standard wheel carriage. The main frame of the vehicle is of cast steel of the box section type with an opening in the center for the recoil of the gun. This mount with the gun located in front and the motor in the rear is similar in appearance to the Schneider 220-mm. gun mount though the front overhang which is characteristic of both is higher up and not so pronounced in the Mark I. The location of the gun to the front of the carriage added greatly to the stability of the mount, though the arrangement hampers loading to some extent.

The motor, which is the 10-ton Artillery Tractor type, is located crosswise and over the transmission.

Fig. 19. S. P. Caterpillar Mount, Mark VII, for the 75-mm. Gun, Model of 1916

Two of the pilot mounts were completed and tested before the Armistice with most satisfactory results and though the total weight is excessive in the light of present efforts, the type, with minor alterations, could be placed in production very readily and would serve as a very useful weapon.

The Mark II, for 155-mm. Gun, Model 1918 MI (Filloux)

In this type the entire top carriage of the standard 155-mm. gun is mounted on a bottom carriage of the pedestal type which is bolted directly to the main frame of the vehicle in such a manner as to give the same elevation as the standard field carriage but with only 10 degrees traverse of the top carriage. The main frame of the vehicle is of cast steel with a U-shaped opening in the rear for the recoil of the gun, which is an improvement over the Mark I in that it makes loading easier.

The motor is located in the front of the chassis under the muzzle of the gun.

The tests of this mount have been very satisfactory, and in firing in competition with the same model gun on the wheel carriage this "Caterpillar" mount proved to be the more stable. Although this gun mount is also considered too heavy, the type with some alterations, including increased elevation, could be placed in production very readily and would serve as an excellent weapon. Eight of this type are now in the hands of troops.

The Marks III and III MI, for 240-mm. Howitzer, Model 1918 [Schneider]

These two mounts are almost identical, the principal difference being in the top carriage frames and main frames of the vehicles, those parts of the Mark III being of cast steel while in the Mark III MI they are of structural steel, and in the latter case no traverse of the top carriage is provided. It was not considered advisable to use the top carriage of the standard field type and the gun was mounted on a specially designed top carriage provided with an auxiliary recoil system consisting of a pair of hydraulic cylinders, one attached to each side of the top carriage frame. The top carriage recoils up an inclined roller path.

The motor is located in the front of the carriage under the muzzle of the gun.

The firing tests were very satisfactory and the stability of the carriage so great as to render the use of the auxiliary recoil system unnecessary. While this mount is in most respects satisfactory as a gun carriage, and takes the place of the five loads of the standard field type, its great weight is objectionable since the weight limit set by the U. S. Engineers for the fixed highway bridge is 80,000 pounds. Apparently it will be necessary to lower the height of trunnions, increase the width of track centers, shorten the length of the vehicle and to resort to the use of outriggers to construct a stable mount of this type which will be within the weight limit set.

The Mark IV-IVA, for 240-mm. Howitzer, Model 1918 (Schneider)

This materiel is almost identical with the St. Chamond materiel previously described and was built from plans furnished by the St. Chamond Company. It consists of two vehicles, a "Caterpillar" gun mount Mark IV, with electric drive, and a "Caterpillar" vehicle Mark IV A, serving as power plant and limber. The frames of the two vehicles are of the same design and are built of structural steel. The tracks and driving motors are of the same designs in both vehicles and are interchangeable.

The top carriage is the same or similar to that of the Mark III and the recoil system is the same. A screw jack form of outrigger is provided to give stability in firing.

The limber is constructed to carry 42 rounds of ammunition in addition to the gas-electric power plant.

In appearance both vehicles are characterized by the overhang in the rear, which would be most objectionable on very rough ground. This type is discussed from the writer's standpoint elsewhere in this article.

Types Developed Since the War: The Mark VII, for 75-mm. Gun, Model 1916

This mount though developed since the war is apparently a continuation of the work started during the war on this type which included tests with a 75-mm. gun mounted

on a 2½-Ton Tractor and which afforded considerable useful information. The field carriage of the 75-mm. gun is mounted on a "Caterpillar" vehicle built up from parts of the 2½-Ton Artillery Tractor model including the transmission, rear drive sprockets, front idlers, track rollers, track and Cadillac unit power plant. The axle of the gun carriage is shortened and mounted in trunnion rests on the side frame of the vehicle.

The tests of this mount were made in the summer and fall of 1919 and were most satisfactory and in firing the mount was most stable with the float type of outrigger with which it is equipped. A speed of 15 miles per hour is readily obtainable on good roads and the mount has been operated under all sorts of field conditions, including deep water, well above the power plant.

The Christie Self-Propelled Wheeled Track-Laying Mount for the 155-mm. Gun, Model 1918 MI (Filloux)

This gun mount, the invention of Mr. Walter Christie of Hoboken, N. J., is a departure from the types heretofore described since it is designed to use chain treads for cross country travel and its rubber tired wheels for high speed on good roads. In Figure 20, the vehicle is shown with the chain treads removed and stowed on the shelves built along the sides of the frame for the purpose. The rubber tires of the eight wheels are 36×6 inches. The four center wheels are adjustable in height and are raised when road conditions permit so as to throw all the weight upon the end wheels. The front wheels are fixed and those in the rear are pivoted for steering when the mount is operated on the wheels.

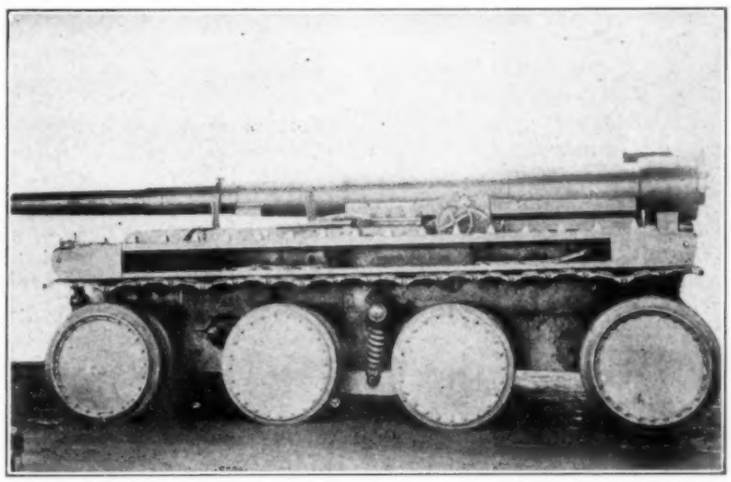


Fig. 20. The Christie S. P. Wheeled Track-Laying Mount for 155-mm Gun, Model 1918 MI (Filloux)

When the chain treads are used the front wheels serve as the driving sprockets and the rear wheels, the axles of which are then locked in place, serve as idlers, the interior wheels serving as the rollers of the ordinary track-laying type. The track shoes are provided with large teeth on the interior sides which mesh with corresponding recesses on the driving wheels. The change from the chain tread system to the wheel system requires about 30 minutes with the present model.

When traveling on the chain treads, steering is accomplished by throwing one side out of gear and applying power to the other. Normally the vehicle travels breech end first, though it was designed to run in either direction with four speeds both in forward and in reverse. In tests the vehicle has given a speed of 17 miles per hour on wheels and 11 miles on the chain treads.

The entire top carriage of the standard 155-mm. gun is mounted on the main frame of the vehicle in the same manner as on the Mark II, and is placed far enough to the rear to give a traverse of 10 degrees either way from the center. The motor and transmission are installed under the muzzle end of the gun.

In the firing tests the vehicle has shown great stability when fired on the chain treads.

Types in Process of Design and Development

The types of self-propelled track-laying artillery now in process of development in this country were designed to meet the general requirements of the "ideal" types recommended in the report of the Westervelt Board which were specified after an exhaustive study of artillery matériels and artillery results of the late war. The recommendations of this Board were wisely made under two classifications, i. e., *Ideal* and *Practical*, the former term being fully explanatory in itself and the second term covering the most practical solution of the artillery problem by the use of the available matériel at hand, coupled with continued test and experimentation with them as well as with later and more advanced ideas. As interpreted by the writer, the trend of the board in characterizing its ideal types of field artillery was toward complete motorization with self-propulsion of the gun carriage as the ultimate goal in all cases other than the railway types.

In its practical solution of the divisional artillery problem the Board presented the following plan: "Practical: While there is no question that the tendency is towards complete motorization, the Board, from a result of its investigation, does not feel justified at the present time in recommending complete motorization of all division artillery. Therefore, it is thought that four regiments of 75-mm. guns (two regiments of French Model 1897, and two regiments U. S. Model 1916) should be immediately motorized; the remainder to be horsed; mechanical transport to gradually replace horse only after the tractor demonstrates its superiority in service. There are various limitations and imperfections in our present tractor equipment which it is believed can only be fully determined by a daily use of this equipment in service." In view of the continued improvement and development of the "Caterpillar" Tractor, self-propelled war vehicles of various kinds and motorized vehicles in general, since the proceedings of the Board were written a year and a half ago, it would appear that we are now ready in this country, to discard the horse and the "equestrian traditions" of the past entirely from our artillery program, to devote our time and energies to the development of the pedestal or other type to give all round fire instead of the split-trail carriage, with a view to its use on the self-propelled chain-tread type of vehicle as the immediate ideal and practical type of carriage for our present and future artillery of all field calibers. It is with the ideals of the Westervelt Board projects that we should busy ourselves and at once put to a practical military advantage in every sense our general motorized superiority over all others.

"Caterpillar" Tractor caissons and "Caterpillar" trailer

caissons were also considered as the ideal companion vehicles for the ammunition service of motorized artillery.

To meet the ranges of the guns of the ideal types, it has been necessary for the Ordnance Department to design guns of greater power and weight than heretofore used and in each type the new design is known as the Model 1920. It is understood that in some cases the new designs will give greater ranges than specified.

The self-propelled track-laying artillery types now in process of development will possess many improvements over the types heretofore constructed and tested, including both the Holt and Christie types which embody many of the essential qualities of ideal types.

Advantages of the Self-Propelled Track-Laying Gun Mount

The advantages of this type of artillery as compared to both horse and tractor drawn artillery are as follows:

Greater speed and more certain mobility over any and all conditions of terrain—including the fording of streams:

(a) Maximum of road adhesion—climbs steeper grades than any other type of traction.
(b) Minimum of road resistance as compared to wheel type.

Permits of all-round fire.

More stable gun mount with less dispersion than wheel type.

Readiness for firing since little or no preliminary preparation of the position is required as with the wheeled types—easily constructed to fire while in motion.

Easily camouflaged.

Occupies less road space, less shipping space and is of less gross tonnage than either horse or tractor drawn artillery.

Greater economy in cost of operation:

(a) Less motor tonnage than any other form of gun traction.
(b) Less motive fuel such as forage for animals or fuel for the tractor drawn type.
(c) Less personnel than either horse or tractor drawn artillery.
(d) Fewer spare parts than tractor drawn artillery.

More convenient for maneuvering the gun:

(a) Power always at hand for sudden changes of position.
(b) Smaller turning radius.

May be used as tractor in emergencies.

No problems of animal life as compared to the horse, which always requires care, food, water and sometimes shelter from the elements; no sanitary problem. Does not suffer from disease, gas, shell-shock, exhaustion or climatic conditions; does not stampede; less vulnerable to damage from war weapons, particularly when motive system is armored; may be repaired or salvaged to great advantage; easier to produce.

Disadvantages

The disadvantages, though of little importance as compared to the many advantages over the other types, may be summarized as follows:

Vulnerability of the motor if unarmored.

Tractive power not available when in combat position (of no consequence as compared to readiness for instant movement).

Requires application, at times, for unfavorable surface conditions, of grousers which are injurious to ordinary roads.

Unit weight higher than either the horse or tractor drawn types.

Status of Track-Laying Vehicle Design

Development of motor vehicles of the track-laying type by the Ordnance Department dates back only to March 2, 1916, when a Board of Officers met at Fort Sill, Oklahoma, and made definite recommendations for the production of track-laying or caterpillar vehicles for artillery purposes. Commercial tractors slightly modified by the Ordnance Department were procured and turned over to a battery of field artillery. The performance of these vehicles furnished the War Department with basic information for the vehicles that were to be developed from then on and up to the present time. The first production tractors built under Ordnance specifications were ordered in the fall of 1917 and were known as the 5 and 10-Ton Artillery Tractors, Model 1917. These tractors, which were armored against shrapnel fire and had a speed of from 5 to 8 miles per hour, were used throughout the World War with satisfaction.

Modern warfare requires speed. The 5-ton and 10-ton types traveled at a greater speed than most automotive engineers believed possible prior to their development, but they do not travel fast enough. Twelve to 15 miles per hour is the speed required for artillery tractors of the immediate future. This means resilient or rubber cored track rollers and springing the vehicle similar to commercial truck practice or developing convertible vehicles which can be changed from track-laying to conventional wheeled vehicles in a very short period of time. Experimental vehicles of the latter type have been built and test runs made with a certain degree of satisfaction.

It is the belief of the Ordnance Department that, with rubber cored track rollers, the vehicle being properly sprung, and with an improved type of track, vehicles can be produced which can run on tracks at a speed from 15 to 18 miles per hour either on or off the road and have sufficient life to warrant their production. Rubber cored track rollers have been developed that will stand up, relieve metal fatigue and reduce common tractor shocks to a minimum. Track development is progressing rapidly and it is hoped that in the near future tracks will be produced which will have a life of approximately 2,000 miles or better. Already light vehicles of from 200 to 2,000 lbs. have been constructed and carried on an improved type of track that has been satisfactory to the Department. Design is now under way of a similar track for vehicles up to 15 tons in weight and it is believed that it will be as satisfactory on the heavy as on the light vehicles already tested.

Although speed is the prime factor to govern future development there are numerous other obstacles that must be considered. Weight is almost as important as speed and must be held down to correspond with the total load prescribed for the prime mover. Vehicles must be more stable than any vehicles produced up to the present time. This means a wide, low vehicle and as long as practicable without affecting its turning. The width of the vehicle is governed by the tread of the vehicle that is to be towed as the towed load should always track with the prime mover. The height should be reduced to a minimum but under all present designs wherein commercial motors are used the height is entirely governed by the motor height plus the ground clearance desired.

Considerable difficulty was encountered with the first vehicles produced, due to the fact that they could not cross streams which a horse could readily ford. This difficulty has now been overcome as shown by various tests that the Ordnance Department has run on the waterproofing of motors. It has proven to be practicable to waterproof commercial motors to the extent that small streams can now be forded without the slightest injury to the motors. With the adaptation of rubber cored rollers and modern tracks the vehicles are as silent as the average commercial vehicle and it is hoped that, with other refinements now under study by the Department, tractors will be produced that will be silent in the future.

The Ordnance Department has been handicapped in the development of artillery tractors as there is little commercial value for the vehicles developed other than for artillery purposes. The natural trend of commercial organizations is to produce rigid construction, slow moving vehicles to travel not over 4 to 5 miles per hour. Vehicles having a speed of even 5 miles per hour are in the minority, being used principally in the old fields and lumber camps. The average commercial tractor used for farm purposes has a speed of but 3 miles an hour or less.

Life of Machine-Gun Barrels*

By

W. W. SVESHNIKOFF

Member A. O. A.

PART I. ABRASIVE ACTION OF BULLET AND GASES

IT is the object of this investigation to study some of the principal factors which affect the life of a machine gun. Previous investigations have been confined to a study of the life of large guns, where firing conditions are different from those of machine guns. The great value of the latter lies in the accuracy of its aim and its rapidity of fire, which are to a great extent dependent upon the construction of the barrel.

The firing of the gun causes the wearing away and surface cracking of the bore, with its gradual enlargement from the breech end. By this means the rifling is destroyed and the projectile loses its velocity and proper speed of rotation, thus causing inaccuracy in flight. At this stage the barrel is considered useless, especially for barrage firing.

The life of a machine-gun barrel is numerically measured by the number of rounds which can be fired before the barrel loses its accuracy. It is difficult to prediet accurately the life of such barrels, as it has been found that there is considerable variation in similar barrels in the number of rounds which can be fired before the barrel is reduced to scrap metal. The life of the machine-gun barrel depends to some extent on some other causes not discussed in this paper, for example: The rate of firing, the number of rounds fired in each burst, the time intervals between bursts, the effectiveness of the water cooling, the type of ammunition used, the cleaning of the barrels, and the atmospheric conditions and temperatures. The effect of temperature and pressure for one shot during the fraction of a second required for the bullet to travel the whole length of the barrel may be described as follows: The combustion of the charge creates an extremely high temperature (about 2,800° C.) with a pressure of about 51,000 pounds per square inch in the breech end. The effect of this high temperature and pressure is greatest near the breech end of the barrel. The pressure and temperature are respectively decreased with forward movement of the bullet because of the increase in available volume of the barrel and the greater heat absorption by the larger exposed surface of the bore.

Fig. 1. Browning Machine Gun, Model of 1917

Relative variation in the diameters of grooves and lands as the firing of a machine gun progresses are shown in Fig. 2. The curves represent measurements made with star gages on six barrels and are accurate within a few ten-thousandths of an inch.† From a comparison of the average diameter of the bullets and the average diameter of the bore in the grooves, it would appear that the bullet is not in contact with the grooves in a majority of cases. Possibly the bullet is slightly enlarged in girth due to the deformation to which it is subjected upon entering the rifling. Consequently, the base of the bullet will in early firing come into contact with the groove, and at the same time the bullet (being of greater diameter than the diameter of the lands) is in contact with the lands, which results in considerable friction. Star-gage measurements show that after firing about 2,000 rounds the grooves at

*Extracts from Technologic Papers of the Bureau of Standards, No. 191.

†The diameter in the lands and consequently in the grooves varies slightly for the separate guns. However, the difference between the two diameters as they increase after a certain number of rounds is practically constant for various guns. The increase in diameters is the same for guns which originally had the same diameters both in grooves and in the lands.

the breech end are eroded to such an extent that the surface of the bullet no longer makes a sealing contact. At the distance of about 21 inches from the muzzle, as shown in Fig. 2, the increase in diameter along the lands is greater than that in the grooves. At about 15 inches from the muzzle and from this point in the direction of the muzzle the increase in diameter in the grooves is greater than on the lands. A continuous increase in diameter on the lands and grooves from the muzzle to the breech ceases at a distance of about 9 inches from the muzzle. This, it is thought, may be due to deposition of volatilized material at this section of the barrel.

The increase in the diameter on the lands is greatest in the breech end and is very slight at the muzzle. This may be explained by (1) the higher temperature at the breech near the burning powder, and (2) the longer interval of time for which this part of the barrel is exposed to the high temperature. This second conclusion is based on Earle's assertion that about 50 per cent of total time of travel of a projectile from origin of rifling to the muzzle is spent in traveling one caliber down the bore. A similar condition obtains to a smaller degree in the machine-gun barrel. The greatest abrasion is naturally at the breech end, where the bullet enters the rifling. The diameter of the lands is gradually increased as successive bullets enter the rifling, and the zone of the greatest abrasion due to this action is extended for a short distance down the bore.

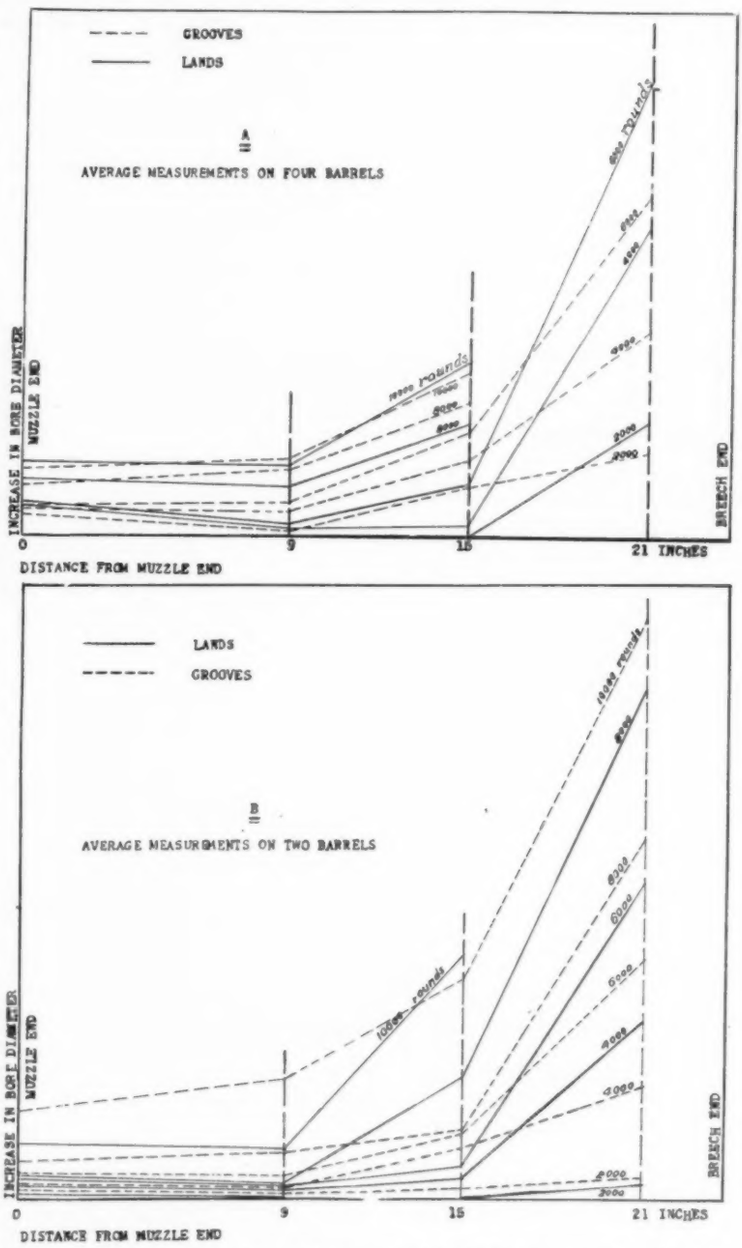


Fig. 2. Graphs showing relative enlargements of lands and grooves of machine-gun barrels with increased number of rounds fired. Star-gage measurements were taken at four different distances from the muzzle end. Relative increases only are available for publication.

The increase in the diameter in the grooves is greater also at the breech and diminishes toward the muzzle. Higher temperature and pressure at the breech end, as previously explained, are responsible for the greater abrasive action of the overheated gases.

The hot stream of gases rushes between the bullet and the walls of the grooves with great velocity. There is slight contact between the bullet and the grooves, and each shot increases the average diameter of the latter by melting or possibly by vaporizing the metal. This washes the grooves throughout the entire length of the barrel. With the resulting enlarged free space between the grooves and the moving bullet, the abrasive action of the gases is increased because of the larger volume of gases escaping through the free space.

It will be noted in Fig. 2 that the differences in the diameter on the lands after 2,000 rounds have been fired is negligible throughout the first 15 inches from the muzzle, while the diameter in the grooves increases considerably in comparison throughout this entire distance. It is also shown that with an increased number of rounds the increase in the diameter of the grooves is greater than the increase in the diameter of the lands. If the wearing away of the surface of the bore by the gases were the same on the lands and in the grooves, the increase in diameter of the former should be at least equal to the increase in the diameter of the latter for the same number of rounds. But the grooves show a greater increase in diameter than the lands, which suggests that the greater erosion in the grooves, over this distance (15 inches from muzzle) is mainly due to the escape of highly heated gases around the seat of the bullet.

Consequently when a machine-gun barrel reaches its life limit its exhaustion is due to a combination of the abrasive action of the bullet and abrasion of gases, but to a greater degree to the former. The action of the bullet obliterates the lands, which results in the destruction of the rifling, beginning at the breech end. The destruction of the rifling causes the loss of the gun's accuracy, thus terminating its usefulness.

Effect of Temperature on the Surface of the Bore

The temperature of the surface of the bore rises rapidly

with the increased number of rounds fired. The effect of the high temperature penetrates only to a slight depth, as the gun is rapidly cooled by the large mass of metal of relatively low temperature adjoining the highly heated layer. In the case of machine guns, the combustion is not completed at the time the bullet leaves the muzzle, and consequently, because of the rapidity of the fire, cold air has no opportunity to enter the barrel and exert a cooling effect. In the case of intermittent firing with the machine gun, air enters the barrel and naturally some cooling is obtained. Below the heated surface of the bore the steel has only a moderate temperature. After a limited number of rounds has been fired, only the thin surface of the bore is injured. This is shown in a microscopic examination of the original cross sections, Figs. 3, 4, and 5. The thin structurally changed surface layer originates at the breech end of the barrels, where the duration of heating has been longest and the temperature highest. The depth and length of this

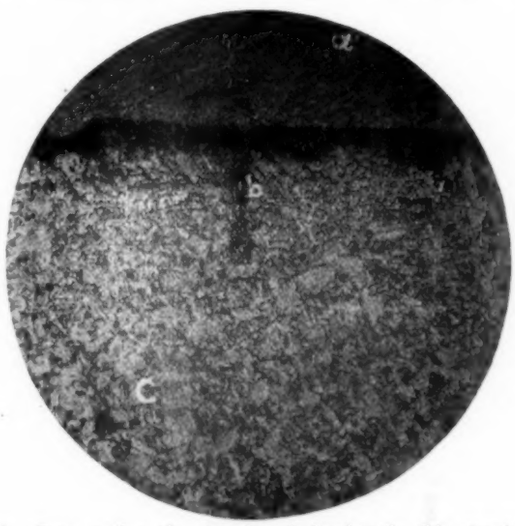


Fig. 3. Cross section of a gun barrel showing the thin structurally changed surface layer caused by firing 3,880 rounds. × 200.
(a) Electroyltic protective layer of copper; (b) Highly heated layer; (c) Original structure of steel.

surface layer depends upon the temperature of heating, and it grows toward the muzzle with continual firing. For a gun fired 8,000 rounds the depth of this layer at the breech is about 0.0013 inch.

Fig. 5 also shows the appearance of the thin white layer on the surface of the bore, but because sufficient information concerning it is not now available its nature and structure are not discussed in the present article.

Intentional Production of Heating Effect by Electric Arc

In studying this phase of the problem experiments were carried out with intentional production of this heating effect on the steel by an electric arc.

The temperature of combustion of nitrocellulose powder is estimated to be about 2,800° C. The temperature of the hottest part of the arc from a positive carbon electrode is estimated to be between 3,600° and 4,700° C., which is considerably higher than the temperature of combustion of powder. In either case a temperature higher than the melting point of steel is obtained. The temperature attained by the metal of the bore increases with an increase in available heat. The available heat is increased by an increased rate of firing. A prolonged exposure of the surface of the gun to this heat would even result in fusion of the surface layers.

According to Prof. Zay Jeffries, depression of the Ae_1 transformation point under conditions existing within a gun at the time of firing should be slight. The change of

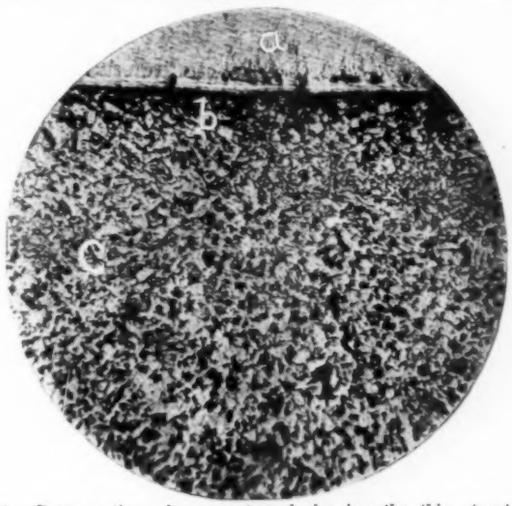


Fig. 4. Cross section of a gun barrel showing the thin structurally changed surface layer caused by firing 8,000 rounds. × 250.
(a) Electrolytic protective layer of copper; (b) Highly heated layer; (c) Original structure of steel.

melting point due to the increased pressure within the gun is so small as to be negligible.

Machine-gun barrel steel stock used for the arcing experiments conforms to the following chemical specification:

Carbon	0.40 to 0.50
Manganese	.60 to .70
Phosphorus	Maximum, .045
Sulphur	Maximum, .035
Silicon	0.20 to .30
Chromium	.40 to .50

Figs. 6, 7, and 8 show the cracking produced in the heated surface by arcing with a copper electrode. The

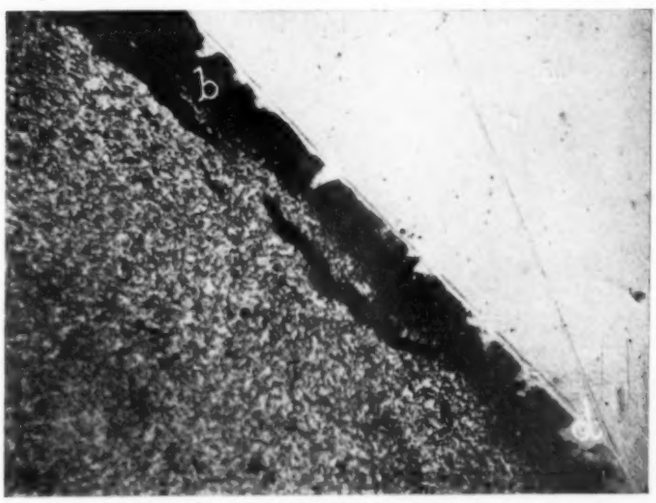


Fig. 5. Cross section of a machine-gun barrel after firing 8,000 rounds. × 250.
(a) Electrolytic protective layer of copper; (b) Highly heated layer; (d) Thin white layer.

structure of the specimen in the area around the crack is entirely martensitic and merges rather abruptly with the original ferrite-sorbite structure in the specimen. Figs. 6 and 8 also show main and tributary cracks following the grain boundaries. The white portion of the specimen immediately surrounding the crack is metallic copper which

has been deposited by the electrode during the arcing. A flow of copper has also occurred along the grain boundaries which are brought out by the high temperature.

To avoid the copper deposit, a specimen of this machine-gun steel was exposed to the heat of an electric arc drawn

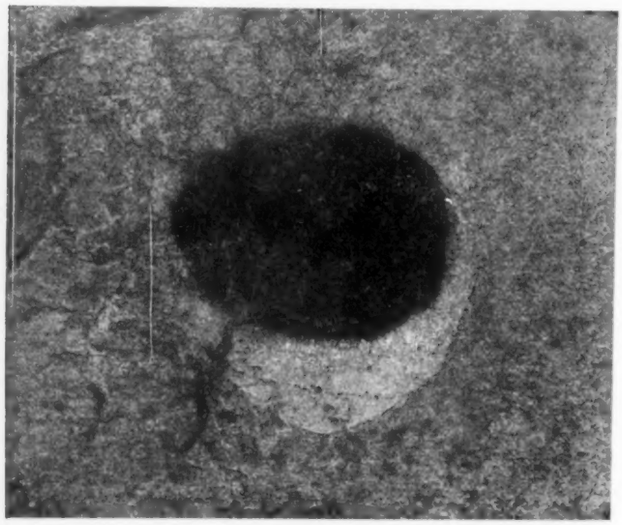


Fig. 6. The cracks produced in the surface of steel by the heat of an electric arc (a copper electrode was used). Etched with 2 per cent nitric acid. × 100.

The dark central part is the hole made by the arc. The white portion of the specimen immediately surrounding the cracks is metallic copper. The structure of the specimen in the area around the cracks is entirely martensitic, merging rather abruptly with the original ferrite-sorbite structure of the specimen.

from a carbon electrode. Fig. 9 shows main and tributary cracks in the surface of the specimen caused by this method of arcing. During this test a reddish brown deposit, which probably consists of iron and manganese oxides, was formed on the surface adjacent to the heated area. This experiment was repeated several times, and in each case a

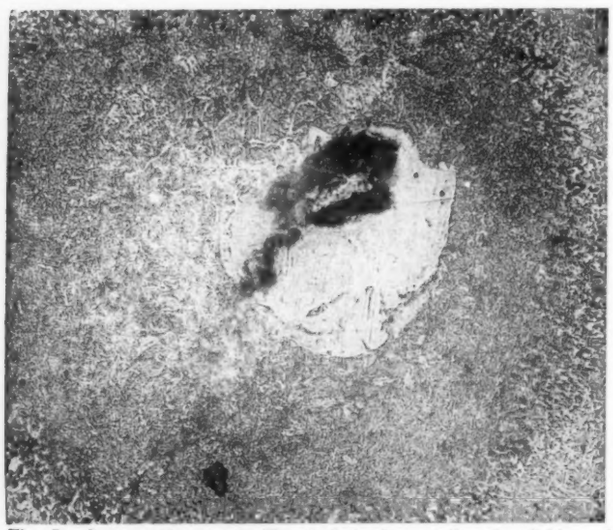


Fig. 7. Same surface as in Fig. 6, but after continued polishing of sample. Etched with 2 per cent nitric acid. × 100.

deposit of iron, spongy in appearance and devoid of structure, was apparent at the point of arcing. The deposit was filled with inclusions, probably oxides, while the structure of the surrounding metal appeared to be martensitic, merging sharply with the original sorbitic ground mass.

Fig. 10 shows the dark grain outline in the martensite bordering the edge of the view shown in Fig. 7.

In the specimen of machine-gun barrel steel examined which had been submitted to ares from the copper and carbon electrodes, the occurrence of grain boundaries is significant of the high temperature to which the metal has been heated. The grain boundaries are best shown in Figs. 6 and 8. They are well developed at a short distance from the fused area, and they end abruptly just within the area which had been changed to martensite. In the specimen heated by the copper electrode the boundaries adjacent to the fused area are filled with copper, but in the specimen heated by the carbon electrode fused iron has filled in the cracks for a shorter distance.

The micrographs show that the metal had been exposed to a very high temperature, permitting volatilization of the amorphous metal between the grains. The amorphous phase has a higher solution pressure than the crystalline phase, and although volatilization would probably occur in both of these phases, the greater loss would occur in the amorphous phase. After volatilization had proceeded along the grain boundaries for a slight depth, the pool of molten metal gradually followed the depressions which had been formed.

Fig. 8. Micrograph showing cracking in the specimen submitted to electric arc from the copper electrode. Grain boundaries developed. Molten copper tends to follow grain boundaries. Indicative of the origin of these boundaries while the copper was still plastic and capable of flowing. Etched with 2 per cent nitric acid. × 100.

The conditons of the change in structure and the grain-boundary development are direct results produced by the high temperature. The pool of molten copper could not have been deposited under a temperature of 1,075° C. The steel fused in the case of an arc from the carbon electrode would not have melted under a temperature of 1,500° C.

In the micrograph shown in Figs. 6 and 8 the branches of the crack appear to show a preference for the grain boundaries. This would also point toward the high-temperature origin of these cracks. It is known that fracture produced in steels at high temperatures is intercrystalline. It has further been demonstrated that the cohesion between adjacent crystals of iron at temperatures above about 650° C. is not as great as the cohesion between units of the same crystals. Furthermore, the maximum expansion or contraction occurs in steel passing through the Ar_1 or Ac_1 ranges. At and above these temperatures the metal lacks sufficient mobility to adjust itself to the rapid changes in volume; consequently internal stresses begin their attack on the weaker portion of the metal; that is, the grain boundaries. By the time a temperature of 550° C. has

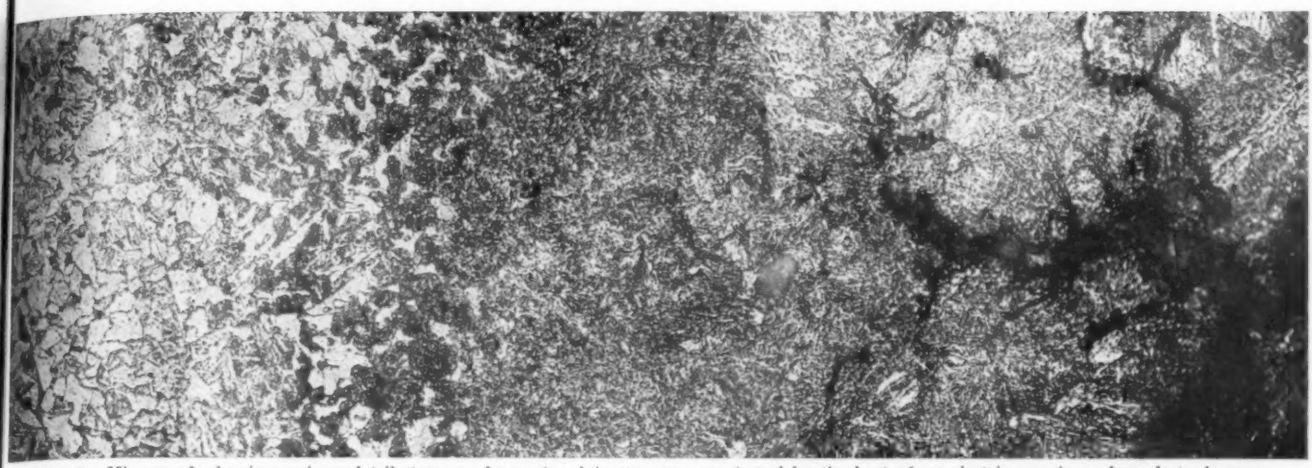


Fig. 9. Micrograph showing main and tributary cracks produced in the surface of steel by the heat of an electric arc (a carbon electrode was used). Etched with 2 per cent HNO_3. × 400.
The microstructure of the area surrounding the crack is martensitic, merging sharply with the original sorbitic ground mass.

been reached in cooling, most of the stresses incident to contraction and expansion have expended their energy and caused the appearance of an intercrystalline fracture. Below that temperature the path of a crack caused by tensional stresses should pass indiscriminately through the metal without regard to its relative crystalline or amorphous condition.

Belaiew and Rosenhain reported that the thin surface layer in the bore of a fired gun consisted of martensite, and the investigations of Prof. H. Fay confirmed their report. Prof. Fay carried out his experiments with pressure plugs, previously subjected to cold work, which were inserted in a gun later fired. In the examination of these plugs he found the effect of hardening with cracking in the vicinity of the cold-worked areas. This indicated that the hardness of the surfacee was due to a combination of mechanical deformation and a process of martensitization. Prof. Fay considered these cracks to have appeared before the change of structure had taken place. Further, the structure, in his opinion, when it first changes appears as troostite, which develops into amorphous martensite. Prof. Fay's observation of a change from the sorbitic to the troostitic structure in the case mentioned did not occur in the specimen of machine-gun steel examined.

It is difficult to conceive of a troostitic structure forming from a sorbitic ground mass, because such transformation occurs in the direction which is the reverse of the usual change. However, the sorbitic ground mass may be transformed into martensite, which sugsequently breaks down and is caught at the troostite transition point. Troostite is a decomposition product of martensite. It usually forms on tempering a martensitic steel, but it can be formed directly by quenching. In either case the martensite-troostite-sorbite cycle appears to favor the formation of martensite before troostite can occur. The occurrence of the amorphous martensite in the surface layer of the gun can be conceded.

Fig. 10. Micrograph showing development and termination of grain boundaries in the martensitic mass. Section taken adjacent to sorbite-ferrite ground mass of unaltered area of the specimen. Etched with HNO_3. × 500.

[Part II will be published in later numbers of ARMY ORDNANCE.]

The Time Element of Fuzes

It is very doubtful if the casual observer has a real appreciation of the importance of the time element of artillery fuzes. In every type of fuze the time element receives particular consideration from a number of viewpoints and must be very carefully regulated to meet the requirements laid down for the fuze in question. To the designer of fuzes it soon becomes apparent that there is always a lapse of time between cause and effect, the extent of which must be determined and controlled within certain definite limits. In other words, the term "instantaneous action" has no place in the fuze vocabulary.

The use of the term instantaneous applied to photography means in the case of high-speed cameras one five hundredth of a second time exposure, and at first glance this appears reasonably instantaneous. However, when dealing with factors of the time equation of a fuze one must deal with very much smaller time units.

As an illustration, a recently developed fuze for use against aircraft is required to explode the projectile within one four thousandth of a second after contact with the target.

In many of the other types of fuzes a definite delay is required between the impact of the projectile and its explosion. Typical cases are the fuzes for projectiles to be fired against armored ships, walls of fortifications, and field gun shell fired against troops in such a manner that the shell strikes the ground, is deflected upward, and bursts in the air. The delays required vary from five to fifteen hundredths of a second for the different types and each delay has its own permissible variations.

Long Range Small Arms Firing

PART V

Effect of Barrel Erosion on Machine Gun Dispersion

By

GLENN P. WILHELM

Member A. O. A.

IT has been shown in a previous article that the character of the dispersion of the machine gun, more than any other factor, has made this weapon one of the most effective pieces of modern armament. The character of machine gun dispersion is dependent to a great extent on the condition of the machine gun barrel which in turn depends almost entirely on the erosion of the bore. This erosion is produced by the combined action of powder gases and bullet friction, the latter effect being relatively unimportant.

When a piece of heavy ordnance, such as a coast defense gun, becomes useless through erosion two results are seen. First, the gun becomes inaccurate and the fire ineffective, a result which is both dangerous and untimely if this should occur during an engagement. Second, the gun must be relined or replaced, which is an expensive proceeding.

It is therefore evident that an increase in length of life is essential for reasons of effective fire and economy. In addition to these two important factors there is, in the case of the machine gun, an even more important reason why it is necessary to increase the length of barrel life to the maximum. One of the most important uses of machine gun fire is for the purpose of overhead fire, i. e., fire directed on the enemy target over the heads of our own advancing troops. In order to avoid this machine gun fire striking friendly troops, it must never be used with a worn barrel as the short shots will surely cause a loss of life which, if inflicted by enemy machine guns, would not be serious, but which, when caused by our own fire, is disastrous because of absolute loss of morale under these circumstances.

Machine Gun barrel erosion is therefore serious from three standpoints:

First. Dangerous use of overhead or covering fire.
Second. Effect of fire.
Third. Economy.

The first two would not be so important if it were possible under service conditions to determine when the barrel had lost its accuracy, and when this point had been reached to change the barrel.

Fig. 1 forcibly illustrates the danger to troops from overhead fire. The black areas at the right indicate the horizontal dispersion of the Browning Machine Gun with service ammunition when fired automatically in bursts of 300 rounds at a range of 2,000 meters. Every third burst is plotted, the rate of fire being very high, about 450 rounds per minute, including all stoppages for any cause whatsoever. Although the elevation is constant the center of impact of each burst is gradually decreasing in range. The dispersion is safe for troops advancing to the assault of an enemy target presumably located at the center of impact, providing the troops do not advance beyond about 1,800 meters range during the firing of the first few thousand rounds. However, any troops over whose head the fire is directed during the firing of the last two bursts would surely be hit by the short shots on account of the great increase in length of dispersion due to the worn out barrel.

The study of the chemical and physical changes occurring in a machine gun barrel from erosion belong to the researches of a metallurgist. This article will therefore deal chiefly with the changes which take place in the flight of bullets due to loss of accuracy in the barrel.

Determination of Rifle Accuracy

The method of testing the accuracy of the machine gun barrel was at first patterned on that of the rifle. This was natural, as a machine gun barrel is essentially a rifle barrel. It is only in its use that it differs. Up until recently the standard of accuracy for the service rifle and ammunition at a range of 500 yards was that no target of ten shots should have a greater mean radius than 7 inches and that the mean radius for six targets should not exceed five inches. This of course was for groups made up of 10 single shots. This method was later modified so as to read that the mean radius for six consecutive targets should not exceed a mean radius of 7.5 inches and this was still further modified to read that no target should be greater than 9 inches.

Determination of Machine Gun Accuracy

In general, the first method of testing the machine gun involved this same system of measurement. The life of the machine gun barrel was considered to be the number of rounds necessary to wear the barrel to the extent that the mean radius of ten shots fired singly from a machine rest at 500 yards would exceed 25 inches. This figure was determined after considerable trial as representing the maximum size of the group permissible considering the relative accuracy of the rifle and the machine gun.

The test usually consisted of firing the gun into a pile of sand at very short range. After every so many rounds the gun was taken out and shot for accuracy and velocity, the barrel in the meantime having been cooled, cleaned and measured. The decrease in the muzzle velocity under such conditions was roughly about 15 feet per second for every 1,000 rounds of firing. Tested in this manner the life of machine gun barrels under various conditions were considered to be about as follows:

Low rate of fire with regular cleaning and oiling. Rate of

fire approximately 1,000 rounds per hour, firing intermittently and oiling frequently. Life, 15,000 rounds.

A failure to oil the barrel in both the above cases at regular intervals appears to decrease the life by 3,000 to 4,000 rounds.

When computing the number of barrels required for an operation the average life of a barrel may be taken as a rough guide at 12,000 rounds.

For ordinary machine gun fire, other than overhead fire, the average life of a barrel is about 17,000 rounds.

Machine gun barrels will continue to function long after the accuracy has been destroyed. In water cooled machine guns the barrel must always be kept covered with water.

Barrels which have been fired over 17,000 rounds are not to be considered worthless, except in active service under conditions which prohibit the determination of their accuracy.

Incidentally, these figures are almost identical with the figures furnished in British Machine Gun text books although this work was independently done. This shows that for this method the figures are reliable enough. It also is fair to presume that the British used the same method.

Fallacy of Rifle Tests for Machine Gun Barrels

The fallacy of these methods lies in the fact that the machine gun was shot for accuracy by single shots *as a rifle*. Machine guns are normally fired in short bursts and the big element in the resulting erosion is the great increase in the amount of heat on account of the rapidity of fire. The artificial pauses for purposes of cooling and measuring, entirely eliminate this heat condition and therefore such a test means nothing from the viewpoint of fire effect. However, this was not clearly realized until an erosion test was held at Borden Brook Reservoir by firing the Browning Machine Gun at comparatively high rate of fire without pausing.

The Revelation of Borden Brook

The following extract from a Borden Brook report clearly shows the great difference between the life of a machine gun barrel fired automatically into a lake (the accuracy being taken simultaneously so that the moment the barrel begins to shoot wildly and short it is immediately apparent) and the life of a machine gun barrel as determined by a "rifle test:"

"A number of recent tests have taken place at the lake, and the barrels usually go to pieces at about the same time, viz.: about 8,000 rounds. In these tests the beaten zone in the water is very small and the gun shoots very accurately up to the point at which the barrel 'goes,' which is very sudden. One moment the beaten zone will be very small and the next moment it will scatter all over the lake, and a barrel, once gone, as long as it is hot and fired automatically usually continues shooting wildly. When the barrel is gone, some of the shots (about 10 per cent) still form a small beaten zone at the original point of impact, showing that some of the bullets are quite accurate. The other 90 per cent string all the way out from 300 to 500 meters short.

"If, however, the barrel is cooled by replacing the hot water in the jacket with cold water and the gun is fired for perhaps as many as 50 rounds or more, the beaten zone will again be small and in the original place. As soon as the gun becomes heated and is going good, the barrel again repeats its former action, and all of a sudden 90 per cent of the shots begin falling short.

"It is apparent that in machine gun firing, barrels are subjected to conditions which are not found in rifle firing. Barrels that have been worn out at Borden Brook for accurate machine gun firing would still fire quite accurately for purposes of rifle fire."

As a matter of fact if the gun is long continued in action after the barrel goes, the shots will continue to strike shorter and shorter until the bullets are landing several hundred yards in front of the gun although the elevation under normal conditions may be sufficient for a range of not less than 2,000 yards.

An inspection of the bullets which fall short will show them to be in some cases almost without rifling marks and as a rule deformed. Also an examination of the barrel after it is cool will usually show the muzzle to be in comparatively good condition although the breech is badly gas cut.

Fig. 2 right shows a typical test at Borden Brook, the range being about 800 yards and the firing inclined down at an angle of five or six degrees.

Fig. 2-B shows the cone of dispersion of a new barrel at the beginning of the test.

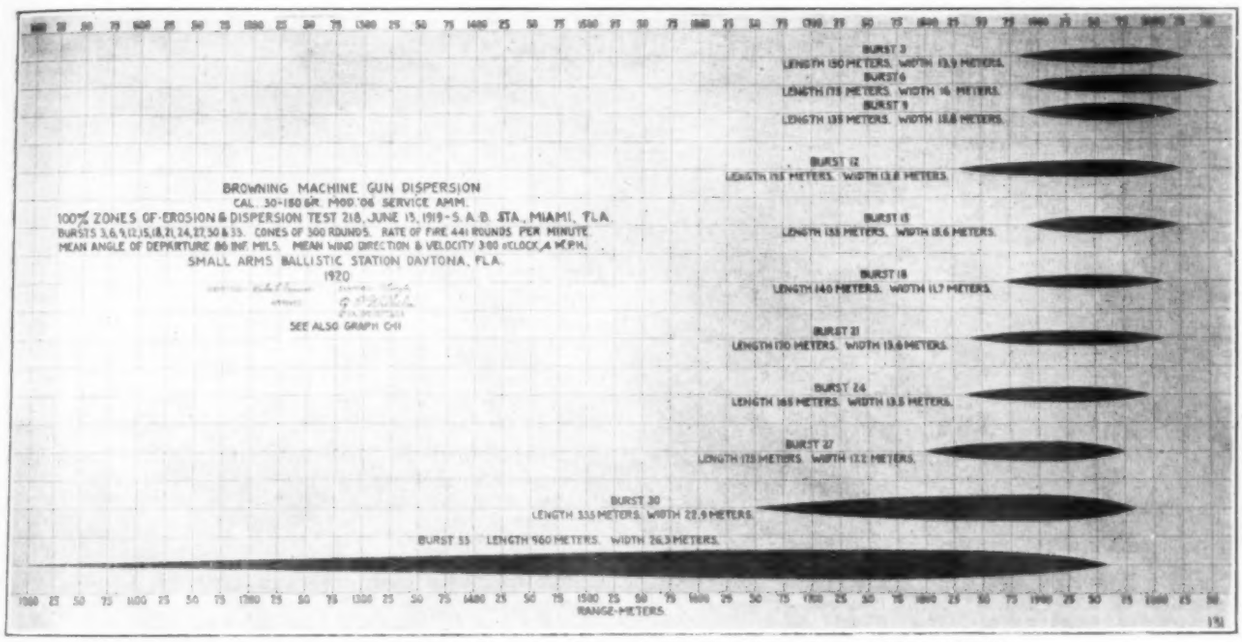

BROWNING MACHINE GUN DISPERSION
CAL. 30-1906R. MOD'06 SERVICE AMM.
100% ZONES OF EROSION & DISPERSION TEST 218, JUNE 15, 1919 - S. A. B. STA., MIAMI, FLA.
BURSTS 3,6,9,12,15,18,21,24,27,30 & 33. CONES OF 500 ROUNDS. RATE OF FIRE 441 ROUNDS PER MINUTE.
MEAN ANGLE OF DEPARTURE 86 INF. MILS. MEAN WIND DIRECTION & VELOCITY 3:00 o'CLOCK, 4 M.P.H.
SMALL ARMS BALLISTIC STATION DAYTONA, FLA.
1920
SEE ALSO GRAPH CHI
BURST 3
LENGTH 150 METERS. WIDTH 13.9 METERS.
BURST 6
LENGTH 178 METERS. WIDTH 16 METERS.
BURST 9
LENGTH 135 METERS. WIDTH 15.8 METERS.
BURST 12
LENGTH 115 METERS. WIDTH 13.8 METERS.
BURST 15
LENGTH 135 METERS. WIDTH 13.6 METERS.
BURST 18
LENGTH 140 METERS. WIDTH 11.7 METERS.
BURST 21
LENGTH 130 METERS. WIDTH 13.6 METERS.
BURST 24
LENGTH 165 METERS. WIDTH 13.5 METERS.
BURST 27
LENGTH 175 METERS. WIDTH 13.2 METERS.
BURST 30
LENGTH 335 METERS. WIDTH 22.9 METERS.
BURST 33 LENGTH 960 METERS. WIDTH 26.3 METERS.
RANGE-METERS.

Fig. 1—Long Range Horizontal Dispersion of Browning Machine Gun. Showing Effect of Erosion

Fig. 2-D shows the slight increase in the size of the beaten zone after about 6,000 rounds of service ammunition had been fired.

Fig. 2-F shows the same test after the barrel was ruined, the shots striking all over the lake as indicated by the faint splashes.

Erosion and Dispersion Tests at Miami, Fla.

The tests initiated at Borden Brook were followed up at Miami on a much greater scale using various rates of fire

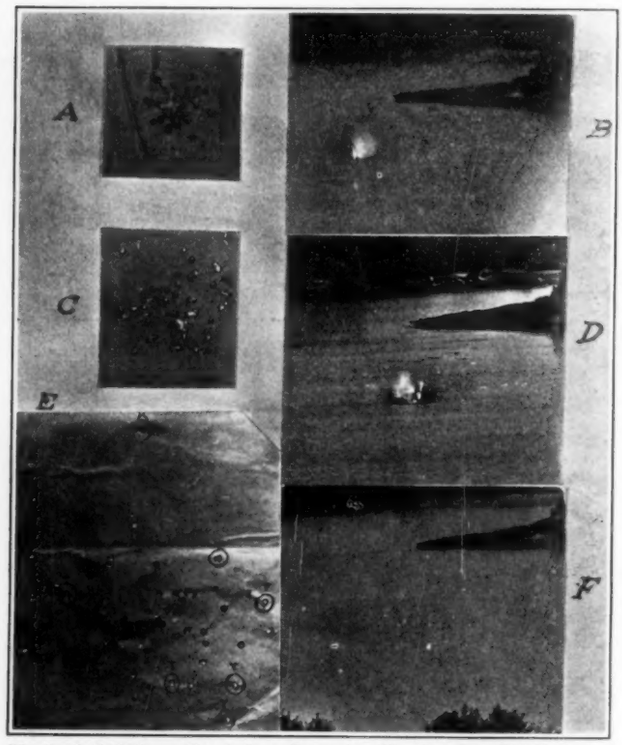


Fig. 2—A-C-E Shows Bursts from Browning Machine Gun Obtained on a Vertical Screen, 1,000 Inches from Gun, with New Barrel, Old Barrel, and Worn-out Barrel, Respectively. B-D-F Corresponds to A-C-E, Except Bursts were Obtained on Water at Inclined Ranges of About 800 Yards.

and with all kinds of automatic weapons. Measurements were also made on a vertical screen 100 feet from the muzzle of the gun for the purpose of observing phenomena accompanying the increase in dispersion.

This made it possible to observe the vertical dispersion in the screen simultaneously with the horizontal dispersion on the water and to make a comparative study of corresponding data.

Fig. 1 illustrates such a test, the dispersion on the vertical screen not being shown. Fig 2 A—C—E shows the nature of such vertical dispersion. Fig 2-A corresponds to Fig. 2-B and to the upper cones plotted in Fig. 1; that is, this group shows the size and character of the vertical dispersion obtained on a paper screen 100 feet distant from the gun when the barrel is comparatively new. Fig. 2-C corresponds to Fig. 2-D and to the lower groups of Fig. 1 (except last group) in that this group was made by a barrel which had been considerably worn. Fig. 2-E corresponds to Fig. 2-F and to the lowest cone of Fig. 1. It was obtained with a barrel which had passed the critical point and was incapable of accurate fire. The shot holes marked with circles were no longer round and showed that the bullets in passing were either "tipping" or "keyholing," i. e., wobbling or tumbling, instead of flying true-point on. Fig. 3—upper shows the horizontal dispersion plotted on sand showing each individual shot in a burst fired from a new barrel. This group therefore corresponds to the upper cones of Fig. 1, and to A and B of Fig. 2. Fig. 3 lower shows some of the individual shots from a burst fired automatically from a barrel which has been worn out. It therefore corresponds to the lower groups of both Fig. 1 and Fig. 2. The dispersion shown in Fig. 3 was obtained with an elevation sufficient to give a normal center of impact with the Browning Machine Gun and service ammunition of about 2,050 meters. The upper group extends from about 1,980 meters to a little over 2,100 meters. Each square represents 10 meters. In the lower figure, however, each square represents 50 meters or five times the scale of the upper figure, the dispersion extending from about 1,200 meters to 1,950 meters. All of the shots were not found due to the great length of the dispersion.

The three figures, then, represent machine gun dispersion during the erosion of the barrel by four different mediums. Fig. 1 shows graphically how the total area of the burst is affected as the wearing of the barrel proceeds. Fig. 2 shows the groups obtained on paper and on water as the barrel wears, the groups being shown by actual photographs. Two methods are represented here. Fig. 3 shows the pattern of the bursts on a sandy beach as obtained at Daytona, Florida. The scale of the groups on the paper screen can be obtained from the diameter of the bullet holes which of course were 3-10 inches. All of the later screen photographs not shown here were made with cross sectioned paper marked in inches so as to facilitate easy scaling.

The following notes were made up as a result of the experience gained in the firing of the foregoing tests:

Effect of Barrel Wear (Erosion) on Machine Gun Dispersion

When the Browning Machine Gun fires service ammunition until the barrel becomes inaccurate (worn out) from erosion, the average number of rounds required to produce this result is usually about 8,000, regardless of the rate of fire, providing the water jacket is kept at all time with sufficient water to fully cover the barrel. With extremely high rates of fire this will necessitate the use of a force pump or some other mechanical device to constantly keep the water changing.

However, the exact time a barrel loses its accuracy depends on so many factors that there is considerable variation in the number of rounds necessary to accomplish this.

When a machine gun is continued in action a sufficient length of time to wear out the barrel, provided the gun is laid with a constant elevation, the phenomena attending the erosion will be about as follows:

The dispersion will not appreciably increase in size until the critical point is reached in the accuracy life of the barrel, after which shots will continue to drop short until finally they only travel a few hundred yards from the muzzle of the gun, although the elevation is sufficient to originally have the center of impact at a range as great as 2,000 yards.

Another peculiarity is that as the firing proceeds the center of impact gradually decreases in range until just before the critical point is reached the range may have decreased as much as 5 per cent.

After the barrel has been ruined, about 10 per cent of the shots still reach the original range. In other words, after the dispersion has increased to the extent of hundreds of yards it is still possible to send about 10 per cent of the shots to the range for which the gun was originally elevated.

When the critical point has been passed bullets will tip and even keyhole in flight, and when picked up will often show little or no evidence of rifling marks upon them.

Sometimes the tipping occurs when only a few hundred rounds have been fired due to muzzle rings appearing in the barrel. In these cases the dispersion will increase in length perhaps 100 per cent with a slight decrease in the range to the center of impact. When this occurs the barrel can still be used for effective fire on enemy targets; in fact, it is exceptionally effective, since the bullets are almost dum-dums

due to their lack of stability; but such barrels should never be used for overhead fire.

Inasmuch as it is impossible to tell when muzzle rings may occur, although they are rather rare, this is one reason more why the safety angle for overhead fire is necessarily large.

It is probable that those cases in which the Hotchkiss Machine Gun was maintained in action in France with a high rate of fire for thousands of rounds without changing the barrel were ones in which similar phenomena must have been produced, and the only effect of such fire was either to endanger the lives of friendly troops, if overhead fire was being used, or to litter up the landscape with comparatively ineffective fire, as any machine gun will long continue to function after the barrel is worn out.

Foreign makes of guns and ammunition, when subjected to the same conditions as service weapons, do not achieve any better results, if as good. This is in spite of the reports which show great numbers of rounds fired through foreign guns with little loss in accuracy.

These reports are probably due to the fact that an inaccurate machine gun barrel will fire, when cold, a comparatively accurate target of ten shots. It is even possible to fire several bursts with a barrel which is cold and has just passed the critical point, and still have good dispersion, but once let the barrel become heated and the bullets will go "all over the lot."

The answer is that the only way to determine the accuracy of a machine gun barrel is to measure the horizontal dispersion with the gun in automatic action as it would be in service conditions, and not to try to accomplish the same result by firing targets of ten single shots with the barrel cold.

Difference Between an Erosion Test and an Accuracy Life Test

After the close of the first Miami Firings a special committee was appointed in the Technical Staff of the Ordnance Department to discuss the standardization of conditions governing tests for erosion in Machine Guns. This committee recommended two types of test in order to determine the erosion in machine gun barrels and the effect of this erosion on the flight of the bullet under normal conditions.

The first test was called an Erosion Test and was described as follows:

"This test to be conducted for the purpose of determining the effect of sustained firing on the interior mechanism of the gun, the effect on the barrel, pressure, velocity, temperatures and physical constants. Such a test will have to be run by stopping the firing periodically, cooling and cleaning the gun, measuring various mechanical parts, etc. The periodical stopping of the test prohibits this form of erosion test from being used as a determination of the accuracy life of the barrel when fired continuously, approximating service conditions."

The second test was called an accuracy life test which was described as follows:

"This test to be conducted for the purpose of determining the accuracy life of the barrel, approximating service conditions, by firing the gun continuously at the maximum effective rate of fire for sustained firing. There will be no pauses or stoppages in the fire for purposes of cooling and cleaning, and the fire will be maintained at the maximum effective rate at which it can be sustained without putting the gun out of action from the mechanical effect of heat on the functioning of the gun."

The first might be called an Ordnance or Metallurgist's Test while the second is more of a service test. The former enables the technical expert to study the causes of erosion and to provide means to reduce it while the latter is chiefly of importance to the troops in the field who are to use the gun in action.

It is comparatively easy to run either type of test where the facilities are such as are available at the new Small Arms Range at the Aberdeen Proving Ground. However, it is a serious matter for troops in the field to readily determine whether a machine gun barrel is still accurate or not. Under such circumstances the following procedure is probably the best method available to determine this question.

Determination of Accuracy of Machine Gun Barrels

Set up two Browning Machine Guns with the water jackets full on the 1,000-inch range, one gun having a new barrel and the other one having the questionable barrel. The guns should be firmly mounted on good tripods with T bases and sand bags. Fire at least three automatic bursts of 100 rounds each from both guns. Do not change the water and take only sufficient time to relay the gun or change the target and still preserve each shot group.

Compare the three bursts from the good barrel with the three bursts from the questionable barrel. Providing the mounts are identical the questionable barrel will be inaccurate if the average size of its groups (for the second and third bursts) exceeds the average size of the bursts from the good barrel by at least 100 per cent.

Examine closely the holes in the screen made by the bullets from the questionable barrel. Regardless of the size

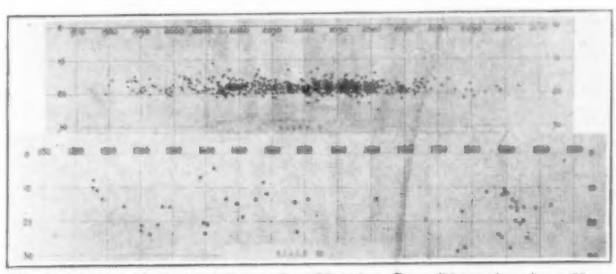


Fig. 3—Upper: Horizontal Browning Machine Gun Dispersion from New Barrel Obtained on Sand, Showing Individual Shots. Range 2,000 Meters. Lower: Corresponding Bursts Fired from Worn-out Barrel. Scale 5 Times that of Upper Drawing.

of dispersion, if the bullet holes are not "clean cut" and round, or show any signs of "tipping" or "keyholing" the barrel will not be satisfactory for *overhead fire* although it might be capable of *effective fire*. The average size of the dispersion from a good barrel with a good set-up should not exceed 3½ inches horizontally by 5 inches vertically, and it is possible under the best conditions to reduce these figures by one-half in each dimension.

A barrel is not accurate if the last four inches of the muzzle are badly worn. It may be inaccurate even if the last four inches are perfect, providing it is badly worn in front of the chamber. Machine gun barrels should be examined periodically to determine the condition of the muzzle (particularly muzzle rings) and the amount of erosion at the breech, for it is the portion directly in front of the chamber, and not the muzzle end, that is washed away by the powder gases.

Questionable barrels or barrels which have been fired over 5,000 rounds should never be used for overhead fire. However, for the majority of peacetime problems, particularly when ammunition is scarce, a barrel can possibly be used to fire over 10,000 rounds.

Machine Gun barrel life is so short and the importance of increasing it so great that every attempt has been made to find some practical method of at least retarding erosion. Innumerable schemes have been tried to prolong the life of barrels by lubrication of the bullet. Such attempts have resulted in failure, as have also schemes to prevent excessive wear by using increased twist in the rifling of the barrel.

It has already been noted in this article under the heading "Determination of Machine Gun Accuracy," how it was formerly thought that failure to oil the barrel would decrease the life of the barrel three or four thousand rounds. This

is not true, as far better lubricants than oil have not been able to accomplish this purpose.

The most promising methods of increasing barrel life appear to be along the lines of cooler burning powders, improved efficiency in shape and material of bullet so as to form a more effective sealing of the bore in order to prevent gas escape and improved material and methods of manufacture for the barrels themselves.

Relative Fire Power of Automatic Weapons

Tests were fired to determine the relative fire power of the three classes of automatic weapons, viz.: machine guns, machine rifles, and automatic rifles. The Browning Machine Gun was taken as representative of the first class and the Lewis Machine Rifle and Browning Automatic Rifle of the last two classes respectively.

The tests consisted of combined erosion and dispersion firings, using each type of automatic gun. In general the tests were divided into two classes: First, an erosion-dispersion test with "intensive fire," i. e. maximum possible rate of fire. Second, an erosion-dispersion test with "sustained fire," i. e., fire maintained at the *highest effective rate* usually considerably less than the maximum rate.

A study of the dispersions recorded in these tests did not show any apparent variation in dispersion on account of the variation in the rates of fire, regardless of whether the variation in the rates was slight or extreme. One of the reasons for this was probably because all three types of guns were substantially mounted thus eliminating all personal error by confining measurements to the mechanical phases.

As has already been stated these dispersion tests showed that the accuracy life of a barrel apparently is little affected by the rate of fire for in the case of air cooled guns if the rate of fire is very high, the gun will become so overheated that it will be impossible to fire a sufficient number of shots to ruin the barrel and thus affect dispersion. For the water cooled guns, the barrel never becomes overheated, providing the barrel is always kept covered with water, and apparently gives the same dispersion and the same life of barrel, regardless of the rate of fire.

Therefore it was found that the most effective rate of fire, when conservation of barrels is the secondary consideration, is almost identically the same rate of fire as is the case when the life of the barrel is of primary importance.

The general results of these tests based on barrel efficiency is that the relative fire power value of the Browning Automatic Rifle being assumed as 1, then it will require from 2 to 8 of these guns to equal the machine rifle, and from 20 to 40 to equal the fire power of one heavy Browning Machine Gun.

However, these figures merely represent the *mechanical possibilities* of these weapons. Their tactical use in battle under service conditions, combined with the factor of the human equation or personal error make it absurd to believe that one heavy Machine Gun is worth as much in battle as 40 Automatic Rifles.

Ordnance at Camp Perry

By EARL McFARLAND

Member A. O. A., Ordnance Officer National Matches of 1921

Have the experiences of the Ordnance Department during the war resulted only in the improvement of heavy guns and means of transportation? Have the great strides of progress in Ordnance development been confined to increasing the range and power of seacoast and field guns and the mobility of artillery weapons?

The expert rifle shots of the country will answer positively in the negative. While the results achieved with heavy artillery have been so spectacular as to cause favorable comment and publicity in the press, the development of Small Arms has also gone forward to the great satisfaction and benefit of the thousands of shooters in America who each year compete for trophies and dollars at the National Rifle Matches.

The National Rifle Matches are conducted under the authority of Congress for the purpose of developing interest and skill in the rifle shots and potential rifle shots of the country. For the last two years the matches have been held at Camp Perry, Ohio, on the excellent range of the Ohio National Guard. The first week of the camp is devoted to instructional work. Team members who are making their first appearance at the matches are given a careful course, not only in shooting but in the methods of instructing so that such men on completion of their work at Camp Perry, are thoroughly qualified as instructors in rifle and pistol shooting and become available for use in a national emergency. The remaining week and one-half of camp is devoted entirely to competitive matches, both individual and team. Winning the trophies for these matches has long been the greatest desire of the competitors who have worked so hard for them year after year.

The Ordnance material supplied for the National Matches of 1921 was so much superior to that furnished in any other year that the most favorable impression was made regarding the service of the Ordnance Department; most satisfactory scores were made by all teams and a greater number of records were broken than ever before.

Among the astounding records made at Camp Perry this year may be mentioned:

Seventy-five consecutive bulls-eyes at 1,000 yards with the Service National Match Rifle, telescopic sight and 180 range bullet.

Seventy-five consecutive bulls-eyes at 1,000 yards with the Service rifle as issued, Service open sights and Service Frankford Arsenal National Match ammunition.

Eighty consecutive bulls-eyes at 900 yards with National Match Rifle, telescopic sight and National Match ammunition.

Seventy-six consecutive bulls-eyes at 800 yards with National Match Rifle, telescopic sight and National Match ammunition.

Eighty-two consecutive bulls-eyes at 800 yards with Service National Match Rifle and ammunition.

The most phenomenal shooting of the Matches was that done by Mr. George R. Farr, a goat hunter of Washington state. Although sixty-two years of age and not experienced as a target rifleman, Mr. Farr took the National Match Service Rifle as issued to him, and without any modifications

Continued on page 173

Springfield Armory

By

T. L. AMES

Member A. O. A.

[NOTE.—A brief history of the National Armory at Springfield, Mass., compiled by Col. T. L. Ames, its present Commanding Officer, from "A History of Springfield Armory," by Lieut. Derwent S. Whittlesey; original papers collected by Mr. Harry A. Wright, of Springfield, Mass., and from the Armory files.—ED.]

SPRINGFIELD, Massachusetts, on the Connecticut River, the home of the Springfield Rifle, was founded by settlers from Massachusetts Bay Colony, soon after the founding of that Colony. They were led to select it as the site for their settlement because here several rivers found their way from adjacent highlands into the Connecticut River, giving access to a large area of mountain and forest land, and here also Indian trails centered from North, South, East and West, marking it as on the natural routes of communication. The immediate object in view was the establishment of a fur-trading post and in this they were eminently successful, their leader William Pynchon accumulating a handsome fortune for his family, and the town prosperity likewise. As years passed and the country become more settled, the fur trade dwindled and before the Revolutionary period was reached Springfield had become relatively of less importance. The town occupied a narrow strip of low land along the river with uninviting sandy pine upland to the Eastward. Northampton and West Springfield, nearby towns, were located nearer fine farming land and prospered correspondingly as farming grew in importance. While on the Connecticut River and sharing to some extent in the river trade, the size of sea-going boats used had already fixed Hartford as the head of such navigation on the river. With the coming of the Revolutionary War conditions arose which soon re-established Springfield as the leading city of Western Massachusetts.

To Colonel Henry Knox is given the credit of first suggesting the need of manufacturing and storage places for munitions, which he did both to Congress and to General Washington in the latter part of 1776. He was made a brigadier general and put in charge of creating such establishments. Pennsylvania was the first state selected for one but shortly thereafter it was ordered by Congress that similar establishments should be formed, one in the Eastern States and one in the Southern States.

Brookfield, Massachusetts, was first chosen as a site for the Eastern States establishment. It lies on the direct road between Springfield and Worcester and was at that time one of the largest towns in this part of the State. Its lack of water transportation seems finally to have decided against it and in favor of Springfield. Consideration was also given Hartford, but it appears to have been too accessible to seagoing vessels and therefore in danger of capture by the enemy. The river narrows and shoals immediately above Hartford prevent sea-going vessels of much size from reaching Springfield, but yet remain useful for shallow-draft transportation purposes to Springfield and above. Springfield was on the direct line of travel between Albany and Boston and already much traffic passed this way because of the war. Another factor in favor of Springfield was that it had within its limits a series of small power sites that could furnish power for the enterprise. Buildings were rented in the town early in 1777 and the work of preparing cartridges carried on in some, while others were used for making carriages for cannon, for repair purposes and for storage.

Immediately back of the town on the highland was a level tract of land, belonging to the town, known as the "Training Field," having been used for training purposes by the militia during the French and Indian wars. An effort was made to purchase this tract of land for the manufacture and storage of munitions. However, the Town of Springfield refused to sell the land at the time, but authorized its lease for a term of years. No record of the lease can be found but in 1778, barracks, shop buildings, storehouses, a powder magazine, etc., were under construction on the Training Field.

Steps were immediately taken to transfer to Springfield all surplus arms and supplies along the New England coast, thus materially decreasing the chance of capture by the enemy. Springfield thus at the outset became a military depot of the first rank.

The American Army functioned in Springfield during the war through three staff groups:

(1) Ordnance, through Col. David Mason, Director of Ordnance.

(2) Quartermaster Corps, through Col. William Smith, Deputy Quartermaster General of the Division centered in Springfield.

(3) Commissary, through Col. Ezekiel Cheever, Commissary of Military stores.

Some idea of the conditions at this time may be obtained from a letter written by an officer from Burgoyne's captured army, who marched through Springfield as a prisoner in November, 1777:

"This place is a veritable magazine for the storage of weapons for the Americans; and it also has a small but very well-built armory or arsenal.

"We saw here various parts of Artillery, with their trains, and among other things, twelve entirely new 4-pounders of French make. The store or magazine houses were filled from top to bottom, and workmen of all trades were seen in the houses engaged in the manufacture of ammunition wagons, guns, etc. * * *"

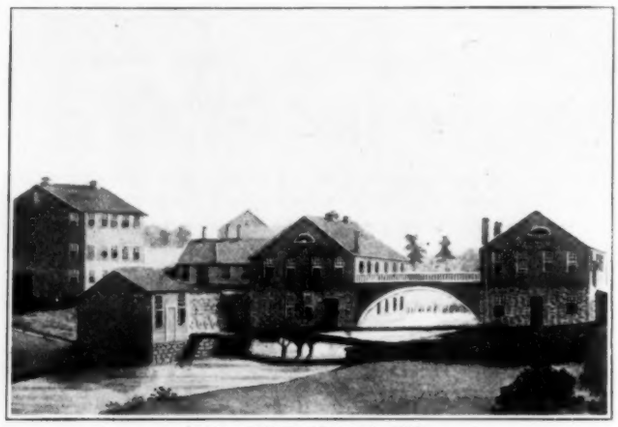
Under Colonel Mason in charge of the laboratory, as the entire group was designated, was a Major Eayrs who had general charge of repairs. Under him were several captains having charge of carpenters, smiths, wheelwrights, etc., respectively.

While all manufacture and repair ceased after the close of the war in 1781, Springfield was retained as a storage point, and to better care for the powder on hand a substantial brick magazine was constructed in 1782 on the end of the Training Field farthest from town.

The culminating act in Shay's rebellion occurred here January 25, 1787. Needing arms and ammunition for his

force he marched on Springfield intending to raid the armory. As he approached the buildings his force encountered artillery fire from a force under the command of General Shepard; several were killed and wounded and the attacking force was broken up.

On October 24, 1789, a few months after General Washington's inauguration as President of the United States,



Upper Water Shops in 1830

he passed through Springfield and the following is quoted from his diary of that date:

"Reached Springfield at 4 o'clock, and, while dinner was getting examined the Continental stores at this place, which I found in very good order at the buildings (on the hill above town), which belong to the United States.

"The barracks (also public property) are going fast to destruction, and in a little time will be no more, without repair.

"The laboratory, which seems to be a good building, is in tolerably good repair, and the powder magazine, which is of brick ,seems to be in excellent order, and the powder in it dry."

Less than a year later William Loughton Smith, of Charleston, S. C., noted that there were at Springfield "public stores of arms and accoutrements, and cannon belonging to the United States; they are kept in very good order. I think there were 8,000 stands of arms, and a large quantity of gun powder."

The only work on small arms undertaken in the laboratory was minor repairs. The manufacture of these arms was in the hands of private firms and individuals widely scattered following the previous custom in this respect of the mother country, England. The war was fought with a great diversity of weapons. A considerable number of arms of the French Charleville model of 1763 were sent to this country by France. Quite a number of them reached Springfield for storage and issue.

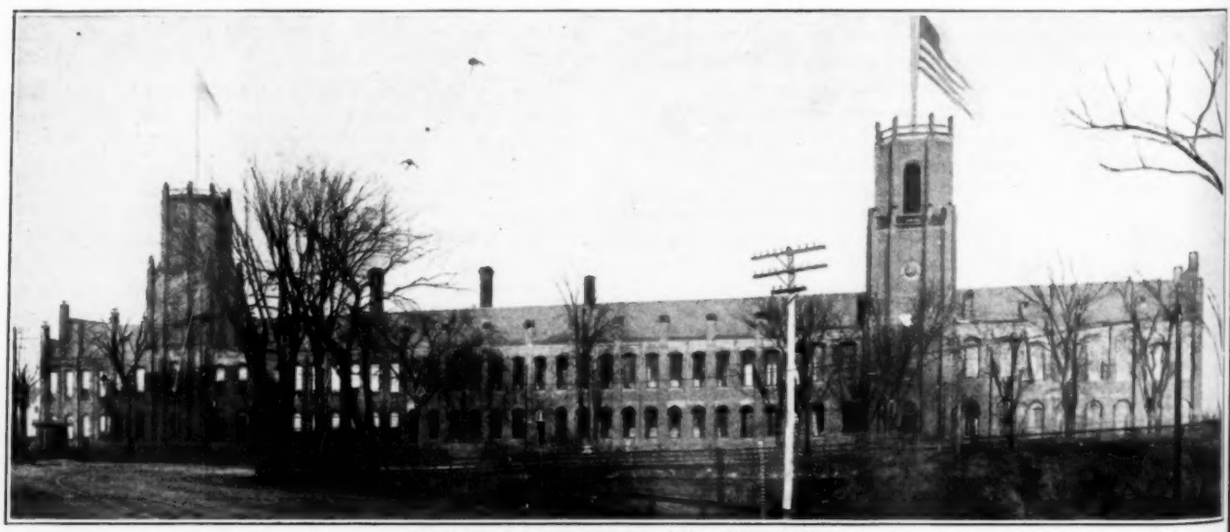
In France quite a different practice as to the manufacture of arms prevailed, for as early as 1535 she had begun their public manufacture, and established the first national armory at St. Etienne in 1669. With the establishment of works shortly thereafter the manufacture of arms was carried on entirely by the government in its own plants.

It is believed that the example of France influenced the newly organized government to a similar course, for on April 2, 1794, Congress passed an act providing for three or four arsenals with magazines and armories attached, their location to be determined by the President. Springfield received special mention as having been previously used. It should be noted that Springfield heretofore had been under State control, the State acting under authority received from Congress.

President Washington after due consideration selected Springfield as the site for one of the arsenals and the Training Field with its buildings was purchased to form a part of that establishment. Other properties were also purchased which included mill sites where water power was available.

One consideration which led to the selection of Springfield originally was still potent and in increasing measure; this was the relatively large number of armorers or gunsmiths in this general vicinity. As it was proposed to manufacture arms in the establishment now authorized, an experienced personnel was needed and would be available in the vicinity.

Springfield Armory as then started and as now existing is made up of two plants known as the Hill Shops and the Water Shops, about one mile apart. The Hill Shops occupy the old Training Field as previously described and the Water Shops are along Mill River, which here finds its way from the high ground to the eastward into the Connecticut River. It provides a number of small power sites within the city limits. Both reservations represent many separate purchases of land, 95 different transfers of land being recorded, the first dated June 23, 1795, and the last August 2, 1870. The pieces so acquired ranged in size from 3 rods to 30 acres 94 rods. One piece of land is held under a 99-year lease. A spring of water was purchased for $37.50. The smallest payment made in the purchase of



Water Shops in 1902 After Completion of South Wing

North and South Shops as Finally Completed in 1918

land was one dollar, the largest eight thousand five hundred. The total paid was ninety-one thousand and fifty-four dollars and thirteen cents. The total area within the three fenced enclosures at the Hill Shops is 57 acres. The area without comprising streets, park, etc., is 16 acres 40 rods. The Water Shops including the area of the mill pond covers 223 acres 138 rods, most of which is comprised in the area of the pond.

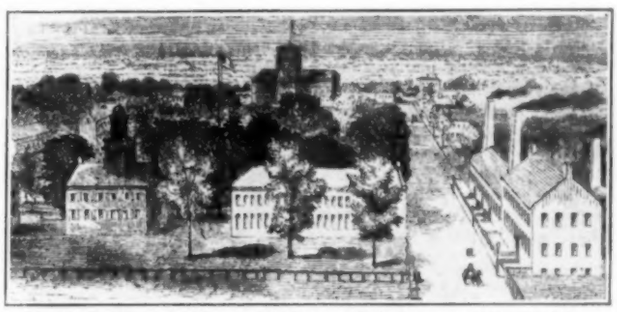
From early days up to 1857 the Water Shops comprised three separate power sites and plants, known as the Upper, Middle and Lower Water Shops, and up to 1844 all power for manufacturing purposes was secured at these plants from Mill River. At one time as many as 23 small water wheels were utilized. In 1857 the Lower Plant was sold and the Middle and Upper Plants consolidated, by lowering the bed of the stream between the two plants so that the Upper Plant had their combined head. At the same time the level of the upper pond was raised ten feet, making a total head of 35 feet.

A new water wheel with direct connected generator of 500 horsepower capacity has but recently been installed here, replacing previous installations, which is more than sufficient to operate the Water Shops in peace time, except in long dry periods, when electric current is obtained from outside sources. Due to fluctuations in the water supply it became necessary to supplement the power from that source by a steam engine in 1861 and this was continued up to the recent war when electric power was brought into the plant from outside sources. Both plants are now fully equipped for group drive by electric motors.

In 1844 a steam engine was installed in the Hill plant and machine operations undertaken there for the first time. From time to time more and more of this work has been transferred to the Hill until now two-thirds of the employees and a corresponding part of the work is performed in that plant. A number of changes have been made in the Power Plant Hill Shops from time to time to meet the changing needs, the last during the recent war when two 625 K. V. A. steam turbo-generator sets were installed. This plant is also connected with outside sources of supply of electric current which can be used to supplement the local supply or as an independent source if the local plant is shut down.

As previously stated the first permanent building at the Hill Shops was the powder magazine built in 1782 with a storage capacity of 4,000 barrels of powder. It was taken down in 1842. The following buildings are grouped around the sides of a rectangle in Armory Square 500 feet by 900 feet: West Arsenal built 1807-8, third story added 1863-4, now the barracks; a two-story stocking and filing shop, part of building now used as Museum, in 1808-9; in 1811 a two-story office building was put up 80 feet south and in line with the last named building; in 1824 the stocking and filing shop burned down and was rebuilt the same year, and a new shop building in line with this and the office building was erected about 80 feet south of the office. These two buildings on either flank of the office were known for many years as the North and South shops respectively. In 1863-4, these flanking shops were connected with the office building and a third story added to the entire group also the tower to the west side of the office and the portico to its eastern front. In 1825 the two-story building known as the East Arsenal was completed. In 1863-4 a third story was added to it, and in 1918 this building was connected with this group by a three story storehouse uniform in architecture with them. In 1830 a three-story building known as the Middle Arsenal was built. It was in line with the barracks and the East Arsenal built a few years earlier. It was the first three-story building on the grounds. In 1846-50 the Main Arsenal building was built, a large three-story building having excellent lines. Along the north side of the rectangle are found the Annex building, the portion that lies along this rectangle having been built in 1808-9; tool house and hospital annex built in 1833; Quarters No. 4, 1836; No. 3, 1898; No. 2, 1894; Quarters No. 5 and 6 were built in 1870.

Of the principal buildings not located on this rectangle, Quarters No. 1 was built in 1844-5; Forge Shop now garage 1863; Long Storehouse, 1846-7, east extension of same 1861, west extension 1863; Dry House, 1863; Experimental Building, 1917-18. Quarters No. 7, 8 and 9 were built in 1833-36 and moved to present location in 1894-5. The new Hill Shops, Federal Square, were built in 1887-92. The main building at the Water Shops was built in 1856-7 and substantial additions were made to it 1862-3 and in 1902.



Sketch of Armory Square, Hill Shops, Made Between 1850 and 1861

The walls of the target house were built in 1906 and the roof added 1917-18.

The smallest number of guns made in any one year since the Armory was founded was in 1795 when 245 were turned out. In 1864, 276,200 were made. The short duration of the recent war combined with the fact that the entire output was used for spare parts from February 7th

to June 17, 1918, resulted in a smaller number of rifles being actually assembled in any one fiscal year of the recent war then during a corresponding period of the Civil War. For 4 months prior to February 7, 1918, an average of 1,125 rifles per day had been assembled. For the months of September, October and November, 1918, an average of 1,428 per day were assembled, or at the rate of about 400,000 annually. This in addition to the usual allowance of spare parts for these arms. The total number of rifles manufactured here to date is 3,818,941.

In 1795, $4,495.75 was expended at this Armory. In 1865, $4,247,998.84 was disbursed and 1918, $10,510,554.51 was similarly disbursed. The total expended at the Armory from 1795 to date is approximately $87,000,000.

In 1795, there were forty employees at the Armory. During the Civil War the greatest number employed at any one time was 2,992 in April, 1864. The greatest number during the recent war was 5,367 on November 7, 1918. During all these 126 years there has been quite a large force employed at the Armory and as the character of the service encouraged steady employment, it has frequently happened that both fathers and sons were here and experienced gained over a long series of years was passed on from one generation to the next. As an example, one employee has been here 37 years, his father was employed here 47 years, his grandfather 26 years and his son 2 years during the recent war. The high class of work demanded at the Armory and the training thus given to many of the residents of Springfield caused this city to become the center of a supply of skilled mechanics and has led manufacturers requiring such help to locate here. Thus in this vicinity may be found the Smith & Wesson Company, manufacturing revolvers; Stevens Arms Company, small arms; Bosch Magneto Company, magnetos; Hendee Manufacturing Company, Indian motorcycles; Stevens Duryea Company and Rolls-Royce Company, high grade automobiles. During the recent war the New England Westinghouse Company operated a large plant here for the manufacture of rifles for the Russian Government.

Principal Service Rifles Used in Our Army, Except the Model of 1917, All of Which Have Been Manufactured at Springfield Armory

Since the Retirement Act of May 22, 1920, became effective 68 employees have become eligible for retirement. These 68 have had an average of 32.2 years' service each at the Armory, the longest single period of service being 58 years and 5 months.

There are now employed here 531 employees having an average service here of 16 years, the longest period of service of any one employed being 38 years. Men trained here have in numerous cases gone to other plants to become superintendents and foremen. It is a common saying that "work done with the hands is never well done until done without conscious effort," and the long period of service of most of the employees here insures such work. To this and the natural pride which men take in a job well done, as well as to careful inspection and test, must be attributed the excellent rifles produced at this Armory.

When the manufacture of muskets was first undertaken at Springfield Armory in 1795, the French Charleville musket was taken as a model and this design was followed with minor variations until 1842, when a percussion model was substituted for the flint lock, the .69 caliber being retained.

The records show that these were not manufactured in any considerable quantity until 1844. Interchangeability of some parts had been attempted for some time but in 1840 a musket known as the Model 1840 was brought out which differed from previous models only in methods of manufacture, these methods being such as to secure complete interchangeability. Large numbers of caliber .69 flint lock muskets manufactured between 1830 and 1842 were later altered to percussion. In 1855 a new model, .58 caliber percussion rifle was manufactured, although manufacture in quantity did not proceed until 1857. Several thousand Cavalry carbines, rifled, and pistol carbines, Model 1855, rifled, were manufactured in 1855-6-7.

The fact that the Indians were armed with rifles finally led to furnishing such a weapon to our army. As the Cavalry were in more constant contact with the Indians than other branches of the service, they were furnished a rifled arm first. The model of 1855 had incorporated in it the Maynard priming device which dispensed with the percussion cap and provided in its stead a primer made up in the form of tape which was placed coiled in a receptacle in the lock under the hammer and was automatically fed out under the hammer when the latter was raised and fired the piece when the hammer fell.

This device was omitted as soon as the Civil War came on, due to the time and expense required in its manufacture. Otherwise the models 1861, 1863 and 1864 did not differ materially from the model 1855 and these models were those chiefly used by the Northern side in the Civil War.

A breech loading arm after J. H. Hall's patents was manufactured at Harper's Ferry as early as 1815 and in 1836 there is evidence that as many as 10,000 had been so fabricated. This and other samples of breech loaders do not appear to have met with great favor until the Civil War, during which a considerable number were in use, principally Spencer, Sharps and Burnside models.

Following the Civil War, for several years quite a num-

ber of the caliber .58 rifles of government manufacture were altered to breech loaders following E. S. Allin's model.

Finally in 1873 the caliber was reduced to .45 and a new model following Allin's modification was brought out which became known as the Springfield Rifle. This breech loading rifle of simple design proved to be an excellent weapon.

This was a period of active development in small arms and numerous tests were made with various models which resulted in 1892 in displacing the Springfield by the Krag-Jorgenson rifle, a caliber .30 with bolt action and magazine.

Further experiment and test led to the adoption in 1903 of a new Springfield Rifle known as the Model 1903, which after eighteen years and minor slight changes is without question the best military arm in the world today. It was designed by officers of the Ordnance Department and civilian employees of the Armory by skillfully combining the best features of all known military arms and supplying deficiencies where they existed, being guided by previous experience with such arms.

Ordnance at Camp Perry

(Continued from page 170)

or refinements whatever made seventy-one consecutive bulls-eyes at 1,000 yards, using Frankford Arsenal National Match ammunition. Although the match in which he was shooting was won by a younger man having a heavy barrel rifle and telescopic sights, the record of old Mr. Farr will stand in the minds of those who saw his shooting as the most remarkable score they have ever witnessed.

These merely confirm the achievement and progress of Small Arms development since the War.

The function of the Ordnance Department at the National Matches is primarily to provide rifles and ammunition which will meet the whims and eccentricities of old-time shooters, and to make rifles and bullets always better than any previously turned out by Government Arsenals. Specifically, the function of the Ordnance Department consists in:

a. Preparing requisition for material required at the National Matches, manufacturing and procuring this material, and shipping it to Camp Perry.

b. Taking care of and issuing the materials supplied in accordance with the requisition, and performing the technical and supply duties of the Department in a satisfactory manner.

The arms and ammunition furnished for the National Matches this year were the result of very careful study at the manufacturing arsenals—that is, Springfield Armory and Frankford Arsenal.

The National Match rifle is the standard United States rifle, Model of 1903, especially manufactured from selected parts, having close dimensions and found by test and experiment to give the best results, both for accuracy and ease of manipulation. Special requirements were set up for this year's National Match rifles, the changes from the standard rifle being decided upon as a result of the observation of the rifle issued at the National Matches in past years. Sears, bolts and receivers were particularly selected as to accuracy and smoothness of working surfaces. The stocks were repeatedly soaked in linseed oil to prevent even the slightest warping subsequent to assembly. The greatest pains were taken to produce barrels with the least possible variation, with a minimum bore diameter of .3005 inches and a minimum diameter of .3085 inches. To avoid setting up internal strains in the barrel, straightening was reduced to the minimum consistent with satisfactory results. Rifling cutters were so carefully honed and set that the interior of barrels were extremely smooth and lapping was not resorted to.

Great care was exercised to secure easy manipulation of the rifle, and the bolt lift was controlled by the careful gaging of parts and stoning of cam surfaces, so that the pull-up of the bolt did not exceed 15 pounds.

Each rifle was targeted for accuracy by an expert rifleman at 200 yards, using muzzle and elbow rests. Five shots were required to be in the vertical strip of the inverted T target (4-inch strip) and not to measure more than 8 inches vertically.

The ammunition issued by the Ordnance Department was special National Match ammunition manufactured at Frankford Arsenal for this Match. The essential differences between this ammunition and the regular service ammunition are as follows:

The bullets are tin-coated.
The bullet weighs 170 grains instead of 150 grains.
The muzzle velocity developed is 2,725 feet per second instead of 2,700 feet per second.

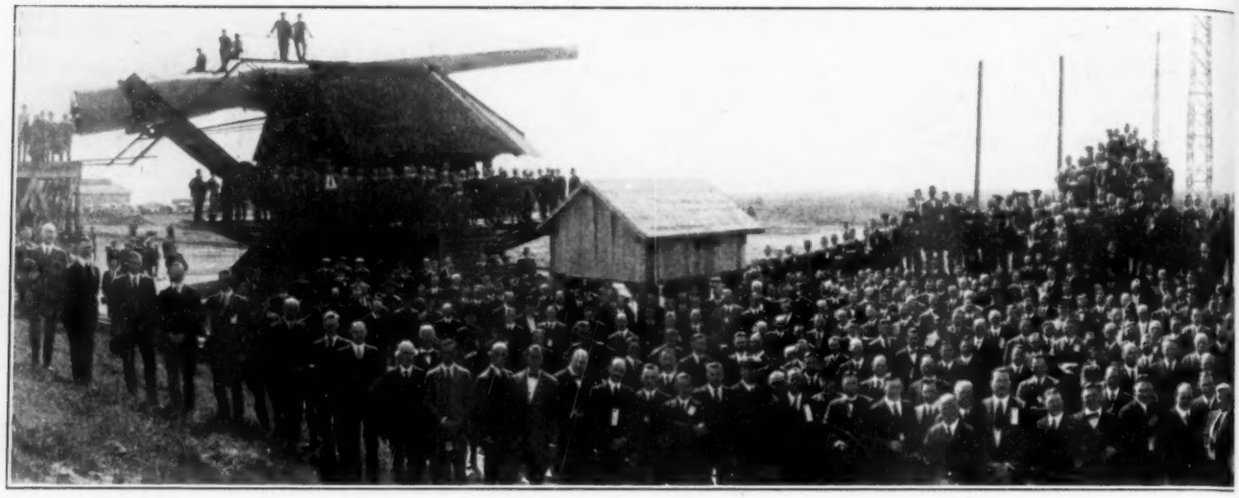
The tin coating of the bullets is obtained by a method of electro-plating which secures a thin, even coat. Following the results obtained with large caliber guns it was found that a small amount of tin mixed with the powder or applied to the bullet would largely prevent metal fouling, thus improving accuracy. This is the first year that a satisfactory solution for coating the bullets has been developed. The results were very satisfactory, and while metal fouling was not entirely eliminated, complaints from this source were very limited. The increased weight and higher muzzle velocity gave better accuracy, particularly at the long ranges, without developing excessive pressure.

It is very gratifying to quote the following paragraph from the 1921 Report of the Director of Instruction of the Camp Perry Small Arms Firing School. This school is held during the first two weeks of the National Match camp and is the forerunner of the Matches.

"The greatest single step of progress attained in this School came through the Ordnance Department. The rifles and ammunition were superior to any ever used by the writer in any previous training school of marksmanship. This high excellence increased the efficiency of the instruction beyond all expectations. It was found perfectly easy to instill confidence in every man in his rifle and ammunition. This is an asset of the greatest value to the instructor and is a great saving in both time and material in training men to any standard of efficiency. Since this ammunition can be manufactured at a very slight cost above the ordinary ammunition, it is certainly available for service conditions, and the results sure to follow its use make it not only more desirable, but also cheaper in producing any given result in marksmanship training. This ammunition proved to be an even competitor at all ranges with the best hand-loaded ammunition, which costs several times as much for production. One of the strongest points in favor of this ammunition is the metallic lubricant of tin. The riflemen have persistently used grease to prevent metal fouling and avoid the chemical solutions in cleaning. The tin plate gives results equal to the best possible use of grease and thus escapes a serious nuisance in training. It was also gratifying to note that the Ordnance Officers in charge of making these rifles and ammunition were present during the entire School, in a careful and sympathetic study of every phase of marksmanship training."

The personnel sent to the National Matches by the Ordnance Office to handle the work of the Department consisted of the Ordnance Officer, who has general charge and supervision of all duties pertaining to the Ordnance Department at the Camp; an assistant Ordnance Officer, who is Property Officer and in charge of the storehouse, and expert mechanics from Springfield Armory and Frankford Arsenal to handle repairs and alterations in equipment and to observe the functioning of rifles, pistols, and ammunition so as to secure the best functioning of the equipment and to obtain information which might be of value in improvements for the next year.

The National Matches are the culmination of the year's activities of marksmanship in the service and in civil life. Upon the arms and ammunition supplied by the Ordnance Department rests the success or failure of the Matches. The shooting element of the country is strong in its influence for adequate preparedness, and during the Matches is the time when the Ordnance Department can show to good advantage its attitude toward target practice and its ability in the manufacture of arms and ammunition. The material furnished and the personnel selected to represent the Department at Camp Perry are accordingly vital to the standing of the Department.



Third Annual Meeting *of the* *Aberdeen Proving Ground*

IN the neighborhood of 1,000 American scientists, engineers, and manufacturers visited the Aberdeen Proving Ground of the Army Ordnance Department on Friday, October 7, 1921, for the purpose of witnessing what preliminary announcements indicated would be a most interesting program of firings and demonstrations of ordnance materiel. As the last visitor hied himself homeward, the consensus of opinion was that there was not an uninteresting moment during the entire program nor a single legitimate complaint against "mess" or transportation arrangements. In fact, one account of the meeting went so far as to state that "The weather was exceedingly fine, and so complete were the other arrangements that the visitors were inclined to credit the Commanding Officer and his staff with this added perfection." Another writer noted "Each demonstration was carefully described immediately before it actually took place. There was scarcely a moment throughout the entire day unfilled with some event of interest."

Frank J. Brunner, well-known military writer, in a thoughtful article in the current number of *The Outlook*, observed:

"The regular service tests of war-making material, which are usually spread over a period of several weeks, were consolidated for this single day at Aberdeen, and the programme proved to be quite as strenuous for the onlooker as a six-ring circus. But when the last gun had been fired the visitors entrained for their home cities convinced that their country could be comfortable even in the face of a war which might threaten to involve it. For just as surely as the ordnance effort of the United States exerted a strong influence in breaking down German morale in 1918, the post-war enlargement upon that effort must make its impress upon war designs of world powers today. From the point of view of army ordnance, therefore, the United States enters the Conference on Armament Limitation occupying a position of strength, whereas this nation would have been compelled, prior to 1917, to occupy at a similar conference a seat among the weakling nations, and, without voice, would have been compelled also merely to listen to the conversations of the strong powers and to accept their estimates as to the allocation of defensive establishments.

"An incident of the day at Aberdeen is illuminative of the great strides negotiated in the span of five years. Out of the sky came a humming airplane; it glided to the landing-field, and from its cockpit, in flying togs, emerged a brigadier general (William Mitchell, Assistant Chief, Air Service) who, while in flight from New York to Washington, called to present his compliments to Major-General C. C. Williams, and to thank him for producing at Aberdeen *the best aerial bombs the world has seen.*"

Inasmuch as modern warfare, typified by the experience of the United States in the World War, calls for the combined effort of the entire population of a nation, in order that the army in the field may be properly supported with munitions and supplies, and bearing in mind the conditions which existed in the United States prior to the war, when little or no co-operation with private manufacturing organizations existed, the Army Ordnance Association was organized with a view to holding together in a common interest that splendid body of trained specialists who devoted their time to the solution of ordnance problems during the war.

(c) BY HARRIS & EWING

Firing of 12-inch Gun from Mobile Railway Mount

Assembled to Witness Proof-Firing of Post-War Ordnance

Army Ordnance Association

October 7, 1921

As one of the objects of the Army Ordnance Association is to foster a closer relationship between American technical societies and the technical departments of the government, with particular attention to promoting interest in ordnance materiel on the part of their membership, an invitation was extended by the Chief of Ordnance to the members of the American Society of Mechanical Engineers and the Society of Automotive Engineers to participate in this annual meeting, making it a joint meeting of the three organizations which, in the event of war, would be most directly concerned with the supply of munitions.

All wars have stimulated the development of ordnance materiel and an attempt has been made by the Army Ordnance Department to apply the lessons of this last and greatest war to the improvement of our armament. What results have so far been reached was well shown at the demonstration at the Aberdeen Proving Ground.

The *New York Times* of Saturday, October 8, 1921, described the meeting in part as follows:

"With a blinding flash and a detonation which awoke the shores of the Chesapeake for miles, the world's greatest gun gave its first public performance here today and opened the third annual meeting of the Army Ordnance Association. The meeting was made the occasion for the first test of the 16-inch 50-caliber rifle mounted on a 'barbette' carriage. With a heavy haze reported over the bay, officers in charge of the program decided to postpone the tests for range, as the 2,300-lb. projectile would have been sent into waters commonly traversed by shipping craft. With an elevation far short of the maximum, the new gun dropped one of the steel shells more than twenty miles away. The gun is electrically operated, and can be traversed and elevated by one man. * * *

"In the evening tests were made with flashless powder. Ten rounds were fired from 75-millimeter guns and not a flash appeared. Instead there was a faint red glow, scarcely perceptible. The invention of the new flashless powder was declared epoch-making by ordnance experts present. Just as elimination of smoke following discharge rendered a battery invisible by day, ordnance engineers and chemists assert that by removing the flash they have 'hidden' their guns from enemy observers by night. In achieving this result they incidentally reduced the volume of the detonation."

The *New York Herald* on Sunday, October 17, 1921, featured a full-page illustrated article by Donald MacGregor reading in part:

"* * * During a day devoted to viewing some of the new and marvelous developments in army ordnance I have just had the opportunity of seeing the various types of tractors adopted as standard equipment for the land

WAR DEPARTMENT
OFFICE OF THE ASSISTANT SECRETARY
WASHINGTON, D. C.

October 12, 1921.

Honorable BENEDICT CROWELL,
President, Army Ordnance Association,
Washington, D. C.

My dear Mr. Crowell:

I wish to congratulate the Army Ordnance Association on the success of the Third Annual Meeting held at the Aberdeen Proving Ground last Friday. It was one of the most interesting, best arranged and best executed affairs I have ever had the good fortune to attend.

General Williams and his Ordnance Officers effectively demonstrated the astonishing progress made in Ordnance developments since the Armistice. I am sure that all of the scientists, engineers and manufacturers who witnessed the program of firings went away with the conviction that this particular phase of preparedness is in good hands.

There is no doubt in my mind that gaining the interest and good will of American industry, as has been so successfully accomplished by your Association, is a valuable asset to the War Department in times of peace and would, of course, be invaluable in the emergency of threatened war.

I wish to assure you of my great personal and official interest in the Army Ordnance Association and my appreciation for what it has already accomplished in the important field of Industrial Preparedness.

Very sincerely yours,

J. M. WAINWRIGHT,
Assistant Secretary of War.

fighters. There are kinds without number, large and small, for every possible purpose. Most of them have been devised since the war, completed from ideas that suggested themselves while the world conflict was at its height. They passed in review in a long line and then, with their funny ambling gaits, proceeded with the more practical demonstration of what they would be able to do in the face of enemy fire. * * *

"The most remarkable of all the development is the tractor artillery, which includes the heaviest of the types of mobile field pieces. Set low to the ground, with belts running around the wheels, these powerful weapons, well protected with armor plate, are able to travel at speeds around twenty miles an hour, which means much in the advance of an army. Some of the heaviest of the guns are assisted by tractor trucks that go a few feet ahead, carrying the personnel that will man them, at the same time generating electrical power which is transmitted by cable to the gun tractor.

"On ordinary occasions these tractors will travel along roads, but it is not essential that they do so. They are able to negotiate any kind of land, cut across fields, get in and out of mud holes and go over country that is under cultivation. The belts around the wheels prevent the heavy loads from sinking into the ground.

"It would be impossible to attempt to describe the various types of mounts that have been provided by the ordnance officers for the artillery of today. They vary almost as much as the types of guns vary, and it is well known that there is a piece of heavy ordnance for almost every possible operation that may be necessary on the battlefield.

Firing of 16-inch 50-caliber Gun on Barbette Carriage

"The tractor plan has been applied also to every auxiliary vehicle that is required in warfare. There are tractors for carrying ammunition, tractors for carrying baggage, tractors for carrying men, and of course various kinds of tanks.

"The heavily armored tanks that are capable of hauling a score of men operating machine guns have been supplemented by smaller tanks to carry two or three. These tiny machines seem much like great bugs as they travel along at high speed. They are virtually land battleships.

"Even more wonderful in their mechanism are the tremendous guns the army has just built for the coast defences. These are 16-inch guns, weighing each 340,000 pounds, firing a projectile of 2,340 pounds. The powder charge is 850 pounds. When they are shot the heavens and the earth seem to rock. Those who stand near by are forced to place their fingers in their ears to save their ear drums.

"There is a belch of flame thirty feet long, a deafening report and heavy black smoke that settles down around the great piece of ordnance. One of these guns, on a disappearing carriage, is intended for the fortifications of New York. Another, which is to be used elsewhere, is on a stationary carriage. The shell is hurled a distance of thirty-five miles, far exceeding any effective range of any other gun.

* * * * * * *

"Across from the administration building about a mile is a great crater in the ground, looking much like the excavation for a ten-story building. It is forty feet deep and measures a hundred feet across. It was caused by the dropping of a 4,000-pound bomb, by all weight and measurement the deadliest piece of ammunition ever constructed. This bomb was dropped by Capt. N. R. Carolin of the Air Service, whose job it is to test out from an airplane the deadly bombs that are devised by the ordnance officers. He carried it up in a Handley-Page airplane, a feat in itself that involved the greatest risk. . . . . Captain Carolin dropped the bomb from an altitude of 5,000 feet, and it was possible a mile and a half away, to follow its course to the ground. It hit long before any evidence of the fact could be observed. Then there rushed up to a height of 500 feet a mighty sheet of flame and earth and smoke. Soon there came across the field a tremendous but muffled roar.

"In observing the crater afterward I found that the force of the explosion was so great that the bomb, 50 per cent of which was TNT, had completely destroyed itself. There were one or two tiny pieces of the casing, but that was all.

"A hundred men digging for a week could not have caused such a hole in the ground. For 500 feet around there was pulverized earth. The leaves were torn off all the nearby trees and the branches twisted.

"The practical purpose of such a bomb as this would be in time of war to destroy the heavy fortifications of the enemy. Only two of these bombs ever have been built. Only one has been dropped. The other is still in the hands of the army, for use in emergency.

"The rapid development of aerial warfare in recent months has led the ordnance experts of the army to devote much thought to defence against them, and it has brought about the completion of a new type of machine gun.

"To demonstrate the efficiency of this gun the ordnance officers sent out a dozen toy balloons to serve as targets. Two of the machine guns were put into action against the balloons, half of the number being pierced by the cartridges that were fired. Standing beside the gun it was possible to follow the rain of steel directed at the flying objects. The line was much the same as the stream of water sent out by a hose. The bullets were three-tenths of an inch in diameter.

"The question of defense against aircraft is receiving, by the way, the utmost study from ordnance experts, and they regard the machine gun just developed as the first step.

"In this connection a machine gun firing 50-caliber cartridges, or cartridges half an inch in diameter, has been built. It is the largest of the kind in the world. This machine gun was demonstrated today with cartridges fired at an old tank 5,000 yards across a field. The bullets were red hot as they chased each other out of the muzzle of the gun.

"It was possible to follow them with the naked eye across the field to the target, which was hit with remarkable accuracy. The demonstration in this instance, as in the others, was not one of marksmanship but one of material. Just the same it showed that such a gun is in a sense an aid to firing.

"It is commonly recognized that what in the end will be the most practical way of fighting enemy aircraft will be with aircraft itself, and for this purpose rapid fire machine guns are being worked on to be mounted in these planes. The army, and the navy too, have had such weapons for a long time, but they have not been wholly satisfactory. The difficulties are, however, being overcome. The

trouble is to get a gun that will not overheat. These are mounted in the rear cockpit of the airplanes and may be fired in all directions, even through the swiftly moving propellers, this arrangement being automatic. It is interesting to note that the 'kick' of such a gun is scarcely noticeable to the occupants of the airplane.

* * * * * * *

"Such developments as these are going on all the time at Aberdeen and at various arsenals maintained by the United States Army. In this work the members of the technical staff within the service receive the help of outside scientists. There is the closest co-operation between them and the American Association of Mechanical Engineers and the American Association of Automotive Engineers. There is, to stimulate the interest, an organization known as the Army Ordnance Association, composed of members of the Ordnance Reserve Corps and manufacturers who might in time of national emergency be called upon to make munitions for the fighting forces."

The Program of Firings in Detail

The first portion of the demonstration was at the railway and seacoast range, where are mounted the larger caliber cannon. Rounds were fired from the 16-inch gun mounted on the disappearing carriage, from the 16-inch gun mounted on barbette carriage, from the 12-inch railway mortar and from the 12-inch railway gun. The 16-inch gun is one of the largest and most powerful pieces of ordnance ever constructed and will throw a shell weighing over a ton a distance of more than 28½ miles.

The railway artillery, while perhaps not new in principle, as there are records of guns having been mounted on railway cars during the Civil War, is one of the most interesting and, in its modern form, one of the most effective methods of utilizing heavy ordnance, both as an aid to offensive operations of an army in the field and in the protection of an otherwise defenseless coast line. The party then examined armor plates that had been pierced by projectiles, and also projectiles that had passed through armor plate. After the firing of the guns at the railway and seacoast battery, a 600-pound bomb was dropped from an airplane in the water impact area nearby.

At the aviation field, which was the next point visited, there was on exhibition a most interesting collection of bombs, comprising all types of American bombs, from the small fragmentation to the great 4,000-pound demolition. In addition to the bombs, a fusilage was set up from a DH4B airplane of the observation and day bombing type, in which were mounted types of synchronized and flexible aircraft machine guns. The airplanes at the field, from the light and speedy scout planes to the great Handley-Page, were examined with interest, as was also the dirigible balloon which was on hand at the proving ground.

At the conclusion of the firing of the aircraft machine guns, the party entrained on the proving ground railroad and proceeded to the visitors' house for luncheon, which was served at about 12:45 P. M. Immediately after luncheon, came the exhibition at the main front, where the following materiel was shown:

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Holt Caterpillar Mount, Model of 1921, for 75-mm. Gun, Submerging

Mobile Artillery Materiel

3-inch Gun Matériel, Model of 1902
75 mm. Gun Matériel, Model of 1897, M I
75 mm. Gun Matériel, Model of 1916
75 mm. Gun Matériel, Model of 1917
3.3-inch Gun Matériel, Model E
75 mm. Gun Matériel, Model of 1920 E
75 mm. Gun Matériel, Model of 1921 E
2.95-inch Vickers axim Mountain Gun
75 mm. Pack Howitzer Matériel, Model 1920 E
105 mm. Howitzer Matériel, Model 1921 E
3-inch Anti-aircraft Gun Matériel using mechanical time fuzes.
155 mm. Gun Matériel, Model 1918, with caterpillar adapter.
8-inch Howitzer Matériel, Model 1918, with caterpillar adapter.

As was the case with the heavy guns, the current testing programs had been so arranged as to permit of the firing of some of the above mentioned pieces as follows:

5 rounds 75 mm. Gun Matériel, Model 1897 M I
5 rounds 75 mm. Gun Matériel, Model 1920 E
5 rounds 75 mm. Gun Matériel, Model 1921 E
2 rounds 2.95 V. M. Mountain Gun Matériel.
2 rounds 75 mm. Pack Howitzer Matériel, Model 1921 E
5 rounds 105 mm. Howitzer Matériel, Model 1921 E
5 rounds 3-inch Anti-aircraft Gun Matériel using mechanical time fuzes.
2 rounds 155 mm. Gun Matériel, Model 1918, with caterpillar adapter.
2 rounds 8-inch Howitzer Matériel, Model 1918, with caterpillar adapter.

In addition to the artillery materiel shown, there were also on hand at the main front types of machine guns, including the Thompson Submachine Gun, the Thompson Autorifle (demonstrated in public for the first time), the Browning .50 caliber and the Browning .30 caliber, together with several forms of mounts, one of which is of particular interest as the latest form of anti-aircraft mount for Browning automatic rifle.

The machine guns were fired with ordinary ammunition and with bursts of tracer ammunition, to test the functioning of the new types, while the .50 caliber gun was trained on a tank which had been used for testing purposes and which was set down the range at a distance of about 600 yards. It is interesting to know that under favorable conditions the machine gunner with the .50 caliber gun shooting at tanks can verify the fact of hitting the mark by the sound of the bullets striking the tank. This sound was distinctly audible at the firing point. It is doubtful whether there is any tank now in existence which could resist the concentrated attack of a section of these guns.

Upon the completion of the firing of the anti-aircraft guns at toy balloons, a second 600-pound demolition bomb was dropped and shortly thereafter the Handley-Page ship, hovering over a point well down on the range, dropped one of the great bombs that was similar in type to that used recently at the bombing test conducted in connection with the sinking of the former German battleship *Ostfriesland*.

As soon as the firing outlined above had been completed the following gun mounts, tanks, tractors and trailers were exhibited and maneuvered for the interest of the party:

75 mm. gun and 105 howitzer, motor carriage, Model 1920
155 mm. gun and 8-inch howitzer motor carriage, Model 1921
75 mm. gun and 105 mm. howitzer motor carriage, Model 1921
Self-propelled caterpillar, Mk. VIII
Self-propelled caterpillar, Mk. I, III, IV

2½-ton, 5-ton and 10-ton caterpillar tractors, towing gun carriages.
2½-ton Div. tractor, Model 1920
20-ton tractor.
"Peoria" and "Syracuse" and reconnaissance tractors.
"Militor" truck equipped with "Chase" track.
Small, medium and large tanks.
"Christie" tank.
British cable suspension reconnaissance car.
Manly hydraulic transmission truck.
1½-ton trailer, cart type.
¾-ton trailer (Dodge parts).
3-ton Christie trailer.
1½-ton trailer, Cleveland type.
"Trailmobile" with cross-country attachments.

The 75 mm. motor carriage, Model of 1920, which is equipped with a waterproof motor and transmission, was run through a pool of water a depth of five feet, for the purpose of demonstrating the waterproof features of the carriage, which is expected to be one of the most useful of the later developments in self-propelled artillery mounts. Its flexibility of control and ability to navigate difficult terrain were well shown and it is thought quite probable that this gun will be able to go anywhere and do anything that horse drawn artillery could do and that quite possibly it may exceed the horse drawn materiel in facility of maneuver and in the rapid occupation of strategic positions almost without regard to the character of the ground traversed.

Upon completion of the demonstration on the main front at about 4:30 P. M., the party was conducted to the exhibition building for the purpose of inspecting the various automotive vehicles in that building and certain German materiel which it kept there. One of the German guns of interest was the 42 centimeter "Big Bertha" which wrought such terrible havoc in the early stages of the World War.

The visit to the exhibition building concluded the daylight program and at about 5:45 P. M., the party proceeded to the visitors' house for dinner, where it was the privilege of many of the visitors to renew old friendships and to make further acquaintance with the members of the Association. The party then proceeded to the main front, where there was a demonstration of flashless powder together with a most interesting test of mechanical time fuses and a demonstration of a trajectory of the 75 mm. gun by means of firing shrapnel with 21 second fuses with ruse settings at 2 second intervals from 20 seconds to two seconds. The rapidity of fire which the 75 mm. gun is capable was well shown by these shells bursting in the air at almost the same instant.

Immediately after this firing, the Proving Ground train left for Aberdeen, to make connections North and South for visitors returning home. The total attendance was in the neighborhood of 1,000 and it is believed that the meeting was one of the most interesting and instructive of its kind ever held. The current programs of test of the various types of new ordnance were arranged to permit of the utilization of the firings for this demonstration, and it is believed that the engineers present were furnished with food for thought which may be productive of still further development in ordnance materiel.

Among those present were the Assistant Secretary of War, Mr. J. M. Wainwright; former Assistant Secretary of War, Mr. Benedict Crowell, now President of the Army Ordnance Association; Chief of Ordnance, Major General C. C. Williams, together with Generals Peirce and Burr of the Ordnance Department; Generals Holbrook, Farnsworth, Hodges, Fries and Mitchell; Colonel W. S. McNair, General Staff, and many distinguished members of the Army Ordnance Association, the American Society of Mechanical Engineers and the Society of Automotive Engineers. A remark of General Mitchell, when questioned as to the quality of ordnance materiel supplied to the Air Service may be quoted as typical of the objectives of the Ordnance Department and of these technical societies which have given so much of their time to ordnance, and that is "Better than any in the world."

Resolution on Chemical Industry

By resolution of the Board of Directors, dated November 8, 1921, the Army Ordnance Association went on record in favor of the enactment of legislation necessary to insure the establishment and permanent maintenance of an independent chemical industry in the United States. The text of the resolution as adopted is as follows:

"Believing in the incalculable peace-time benefits which accrue from the development of the science of organic chemistry and its application in agriculture, medicine, and the industries connected with food, fuel, textiles, and dyes;

"Realizing the great role that organic chemistry has played in the development of ordnance explosives and gases, and that progress has been checked by the hesitancy of the United States in enacting legislation to protect this industry,

"*It is Therefore Resolved,*

"That we urge upon Congress the necessity of enacting such legislation as will encourage the complete development of a permanent, independent chemical industry in the United States to serve this country in time of peace and to insure a trained chemical personnel and adequate equipment and supplies for instant use in time of war; and we express the confident hope that, in view of the important bearing of such action on economic development and on national defense, our representatives, regardless of political affiliations, will support this legislation."

There can be no question as to the vital importance to any nation, either in peace time or in war, of the development of the science of organic chemistry. America seems to be the only nation today which does not realize its importance. In peacetime, its application in agriculture, in medicine, and the industries connected with food, fuel, textiles and dyes, constitutes the key to prosperity. In war, it is the real vital power. The strength of an army is today measured by the amount of chemical power which it is able to turn loose on the enemy—either in the form of explosives, gases or other chemical materials. The history of warfare shows that its development absolutely hinges around the effort to efficiently use chemicals. It is the heart of munitions.

For a long time prior to the World War, the German nation maintained a world monopoly in the chemical and related industries, with the result that Germany alone was thoroughly prepared at the beginning of the war with plants, personnel and materials ready for the immediate production on a war scale of explosives, gases, etc.

The governments of our late associates in the World War, including Japan, England, France and Italy, have already sought to safeguard their future by appropriate legislation. The United States stands hesitant, heedless of the lesson of the summer and fall of 1917 when we were tremendously concerned about the supply of explosives. We have always been behind in chemical knowledge. Practically all new developments have been obtained from abroad and we have been followers in military chemical knowledge, rather than on a par with other countries. A permanent, independent chemical industry in the United States would give us a large reservoir of trained chemists to tap in time of need and we would have their plant facilities which in many instances are adaptable to strictly war needs.

The importance of the chemical industry from the standpoint of National Defense has been urged by the Secretary of War, the Secretary of the Navy, the General of the Armies, and other high authorities, and the above resolution places the Association squarely on record as supporting them in respect to one of the most vitally important problems of preparedness which now confront us.

Artillery Division Notes

4.7-inch Gun—155 mm. Howitzer Motor Carriage, Model 1922—

The design of a motor carriage upon which will be mounted interchangeably either the 4.7-inch gun or the 155 mm. howitzer is nearing completion in the Ordnance Office. The design studies and general drawings are being made in this office and detail drawings will be made at Rock Island Arsenal where the pilot carriage is to be constructed. It is expected that this motor carriage will be ready for test the early part of the summer, 1922.

Two preliminary designs of this motor carriage have previously been made, one by the Ordnance Office and one by the Holt Manufacturing Company, Stockton, California; both having been larger than the present design. It has been decided to reduce the size and weight as much as possible, consistent with good design.

The gun, howitzer and the recuperator are used without any change from the field carriages. A new top carriage and traversing mechanism has been developed. The frame is a built up box construction including at the rear end a steel casting in which is carried the transmission and the gun pintle, and to which are fastened the outriggers, the track driving sprockets, and the rear spring shafts which support the frame upon the trucks. The front of the frame is supported upon the trucks through an equalizer which eliminates weaving strains due to traveling over uneven ground.

The motor carriage will be propelled by a Sterling, 4-cylinder, 5¾-inch bore, 6¾-inch stroke, dual-Valve-in-Head engine with all cylinders inclined at 45 degrees, developing 150 H.P. at 1,500 R.P.M. The lubrication is by pressure pump from an oil tank located outside the engine crank case. Cooling is by means of a Modine Radiator with fan and water pump circulation. Ignition is by means of a K.W. magneto with impulse starter. A Northeast Electric Starting system is provided.

The transmission has three speeds forward and one reverse. Steering is by means of a steering clutch and brake for each track drive. Both steering clutches and master clutch are of the disc type (metal to Raybestos) and are held in engagement by spring pressure.

The controls consist of a steering column, upon which is mounted the gas and spark levers, a foot pedal brake, a clutch pedal, a hand brake lever and a foot accelerator. Such controls as starting, ignition, choke, etc., are mounted on the dash at the back of the engine hood.

A single truck frame is used with a constant spring pressure applied to the front track sprocket for the purpose of keeping the track always at the proper tension.

The track construction has not been definitely decided. The Ordnance Department is in touch with experts of the Goodyear Rubber Company who are collaborating in the problem of silencing and reducing shock on the track.

This motor carriage will have a maximum speed of 20 miles per hour at 1800 R.P.M. of the engine.

Total weight of Motor Carriage (estimated)	20,000 lbs.
Total length of Howitzer	150 inches
Weight of Howitzer	4,265 lbs.
Maximum overall length of vehicle	165 inches
Maximum overall height of vehicle	73 inches
Maximum overall width of vehicle	91 inches
Height of trunnions above the ground	56½ inches
Center to Center of Tracks	78 inches
Width of Tracks	13 inches
Length of track in contact with ground—	
a. Minimum contact on hard surface	70 inches
b. Contact length (3-inch depression)	115 inches
App. ground pressure (on hard ground)	11.8 lbs. per sq. in.
App. ground pressure (3-inch depression)	7 lbs. per sq. in.

Road speed at normal motor speed (R.P.M. = 1500)

Low speed = 2.5 High speed = 16.5

Intermediate = 7 Reverse speed = 2.8

Maximum Traverse, degrees, 15 right; 15 left.

Maximum elevation, 60 degrees.

Horsepower per gross ton of weight 15 H.P. per ton

Service Test of Divisional Motor Carriages—

Shipment has recently been made from the Aberdeen Proving Ground, Maryland, to Fort Sill, Okla., of pilots of two types of new divisional motor carriages for service testing by the Field Artillery Board. These divisional motor carriages mount interchangeably either the 75 mm. gun or the 105 mm. howitzer of the new long range types recommended by the Westervelt Board. Both types of divisional motor carriages were designed for sustained running speeds of from 12 to 15 miles per hour on the road, with a maximum for use in case of emergency of 30 miles per hour on good roads. In order to effect as much economy as possible in the development of these motor carriages, guns, howitzers, recuperators and mounts as used on the regular field carriages have been utilized without modification.

The question of an armor plate shield for the protection of the cannoneers of the Divisional motor carriage against front, flanking and overhead fire with the carriage in either the firing or the traveling position has received a great deal of thought and consideration. As yet no solution which is considered entirely satisfactory has been arrived at. An armor plate shield to satisfactorily protect the cannoneers under the various conditions becomes quite heavy and there is some question as to whether or not it would be needed at all times. A detachable, collapsible shield has been manufactured for the motor carriage Model 1920 (Holt type) and shipped to Fort Sill, Okla., where it wil be tested by the Field Artillery Board in connection with the test of the carriage.

Two pilots of each of these two new types of Divisional motor carriages were manufactured. One pilot of each type will be tested under direction of the Chief of Field Artillery and the other by the Ordnance Department at the Aberdeen Proving Ground, Maryland. This arrangement affords the opportunity for a very complete and comprehensive test of the present stage of development of the Divisional Motor Carriage as both types will undergo a test of an engineering nature at the Aberdeen Proving Ground and an actual service test by the Field Artillery where not only weaknesses or shortcomings due to design will be developed but also the advantages and disadvantages of various design features from the viewpoint of troops utilizing the material in service.

The 75 mm. gun—105 mm. howitzer motor carriage Model 1920 built at the Stockton, California, plant of the Holt Manufacturing Company follows the general lines of design of the conventional "Holt Caterpillar" type of a track laying vehicle and in addition embodies various new features necessary to insure a long life of the vehicle with the high speeds required of divisional motor carriages. The entire vehicle is thoroughly spring supported but in order to further eliminate shock and vibration and reduce noise as much as possible rubber has been used on the drive sprockets, front idlers, track supporting rollers, the forward truck wheel and on the track shoes themselves. The application of rubber to these various parts has accomplished the desired results and has been installed without special difficulty except in the rubber pads on the track shoes. On the track shoes, the quality of rubber as well as the design of the rubber pad requires further experimentation and this problem is being considered by the Ordnance Department with one of the leading rubber companies of the country. This motor carriage complete weighs a little over 13,000 pounds.

The 75 mm. gun—105 mm. howitzer motor carriage Model 1921 embodies the Christie patented feature of a combined wheel and track laying vehicle and was built by Mr. Walter Christie at the Front Drive Motor Company, Hoboken, N. J. This motor carriage normally operates breech forward both

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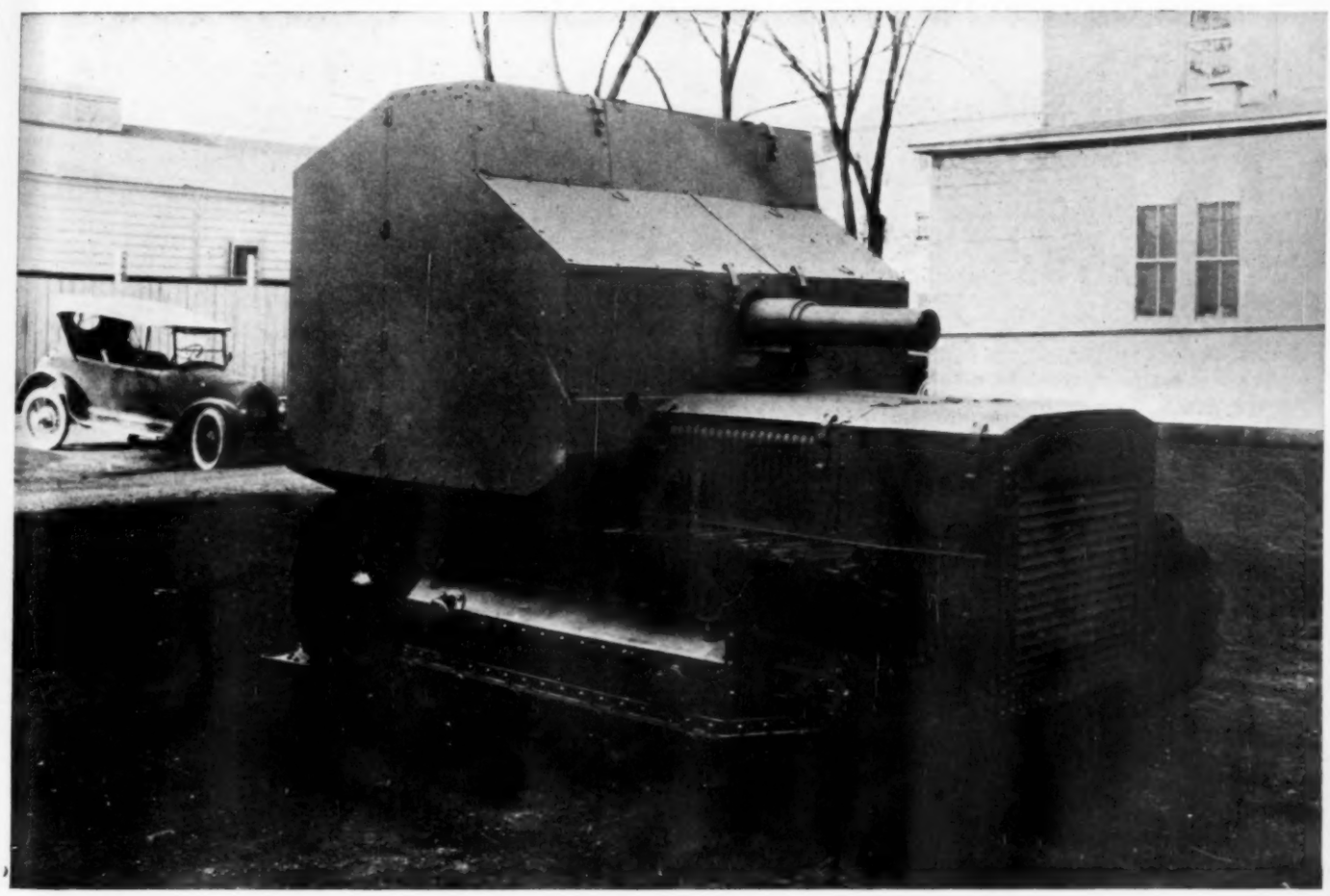
75-mm. Gun—105-mm. Howitzer Motor Carriage Model of 1921 (Christie Type)

Above:—Firing Position, 45° Elevation

Below:—Traveling Position



75-mm. Gun—105 mm. Howitzer Motor Carriage, Model of 1920 (Holt Caterpillar Type)

Above:—Firing Position, 45° Elevation

Below:—Traveling Position

when running on the rubber tired wheels or when maneuvering off the roads with the tracks around the wheels. It can, however, be operated muzzle forward, although when operating on the tracks it should run only short distances muzzle forward as in this case the slack of the track is on the ground side which is not the best operation for a track laying vehicle. The total weight of motor carriage is a little over 18,000 lbs.

This motor carriage is spring supported at the breech end only, but considerable cushioning effect is had from the rubber tired wheels over which the track passes when the carriage operates as a track laying vehicle. When running on the road the tracks are removed and the motor carriage operates as a rubber tired truck. Special Overman rubber tires are used on this vehicle.

Conference on Motor Equipment Design—

Mr. Pliny E. Holt, of Stockton, Cal., Vice-President, in charge of engineering of the Holt Manufacturing Company, recently visited the Ordnance Office, Washington, D. C., and attended the meeting of the Army Ordnance Association at the Aberdeen Proving Ground, Maryland, on October 7, 1921. The Holt Manufacturing Company is co-operating very closely with the Ordnance Department in the development of "Caterpillar" vehicles for army equipment. In conference with Mr. Holt, the latest developments and features of design of this class of vehicle, both for commercial and military uses, were discussed. Such personal contact and detailed discussion of related problems foster a close relationship between the Ordnance Department and Industry of the country and insures that commercial progress and development are incorporated in army equipment.

Rock Islsnd Notes

105 mm. Howitzer Carriage M 1921 E—

A carriage for the 105 mm. Howitzer, Model of 1920 M2-E has recently been completed at this Arsenal. It is known as the 105 mm. Howitzer Carriage, Model of 1921E, and is a companion carriage for 75 mm. Gun Carriage, Model of 1921E.

The new carriage is lighter than the howitzer carriage of 1920, but uses a projectile having the same weight and muzzle velocity as the 1920 carriage. This increases the ratio of projectile energy to weight of howitzer and carriage 24 per cent, which is desirable.

A preliminary proof firing program has been completed in order to adjust the recoil mechanism and parts of the carriage. The first shot indicated that the length of recoil was too great and the counter recoil was too slow. The length of recoil was shortened by changing the lift of the throttling valve and the time of counter-recoil changed by enlarging the orifice of the buffer valve.

A point of interest in this recoil mechanism is the aluminum regulator body which has always heretofore been made of high grade steel. Difficulty was encountered in obtaining a piece of aluminum which was sufficiently dense and free of blow holes. An Ami forging was obtained of the Aluminum Manufacturers, Inc., which in every way met the requirements. It was easily machined to the high finish and narrow limits required by this piece. The use of aluminum reduced the weight of the piece to one-third that of a similar steel piece.

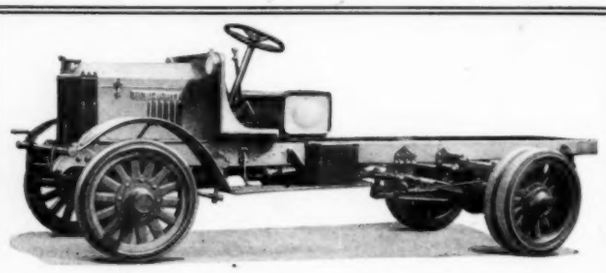
The use of this metal to replace steel for such parts of the recoil mechanism as glands, followers, stuffing boxes and piston bodies is being considered.

Two types of equilibrators are furnished with this carriage One of them is the ordinary spring equilibrator which employs helical springs to overcome the preponderance of the howitzer. The other is a pneumatic equilibrator which employs compressed air. The preliminary tests made at this Arsenal were not extensive enough to determine the merits of each type. The spring equilibrator gave the lightest hand wheel pull. It is thought that by adjusting the pressure in the pneumatic type the pull could have been made the same.

Finishing Trunnion Spindle Casing Hemisphere—

The anti-aircraft mounts which are being manufactured at this Arsenal in the experimental department have the gun, recoil mechanism and elevating and traversing mechanism carried on a central spindle which passes through the center of the trunnion spindle casing. The casing in order to permit leveling is supported by a hemispherical seat in the pedestal.

The finished turning and grinding of the hemisphere on the spindle casing was performed on an ordinary 30-inch lathe without the use of an expensive fixture. A circular table was fastened to the ways of the lathe. On this circular table was secured a compound tool rest. In the tool post of the rest the tool was fastened and given a circular motion by turning the table. When grinding, the tool rest was replaced by a grinding head.



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